INVENTOR MOTIVES, COLLABORATION AND CREATIVITY

A Dissertation
Presented to
The Academic Faculty

by

Yeonji No

In Partial Fulfillment
Of the Requirements for the Degree
Doctor of Philosophy in the
School of Public Policy

Georgia Institute of Technology

December, 2013

INVENTOR MOTIVES, COLLABORATION AND CREATIVITY

Approved by:

Dr. John P. Walsh, Advisor
School of Public Policy
Georgia Institute of Technology

Dr. Mary Frank Fox
School of Public Policy
Georgia Institute of Technology

Dr. Gordon A. Kingsley
School of Public Policy
Georgia Institute of Technology

Dr. Paula E. Stephan
Andrew Young School of Policy Studies
Georgia State University

Dr. Christina Shalley
Ernest Scheller Jr. College of Business
Georgia Institute of Technology

Date Approved: November 11, 2013

ACKNOWLEDGEMENTS

When I decided to go to graduate school, I could not have imagined what was to come. As of this moment, my story has a happy ending, and now I can show my gratitude to the large number of people who helped me throughout this journey.

I sometimes wonder what the story of my life would have been without John Walsh. I started my freshman year in graduate school with John; his class, his exam, and his comments. Now that I am closing this chapter, I see myself grown up so much both intellectually and personally. John has been not only a good mentor and advisor, but also a good friend to me. Without his advice, understanding, encouragement, and patience, I am sure that I would not be able to relish this moment of writing my acknowledgements. My gratitude also goes to my committee members, Mary Frank Fox, Paula Stephan, Christina Shalley and Gordon Kingsley. Dr. Fox's kind, passionate advice and encouragement drove me to finish this job, and I will never regret doing that. I will not forget the moment when Paula graciously accepted a position on my committee, nor our talks in D.C., Tokyo and Milan. Constructive and warm comments from Gordon and Christina will be always remembered. Moreover, I would like to thank Hideo Owan, Sadao Nagaoka, and Yasunori Baba in Japan. When I felt stranded, Sue Rosser and Sheldon Gen from San Francisco State University generously provided help, and I really appreciate that.

In addition, I have enjoyed working and being friends with Hsini Huang, my BFF at Georgia Tech. Without her support, I would not have been able to come this far. Of course, I will always remember the golden phrase from Taehyun Jung, “Search the help tab,” and his support in the back. My gratitude also goes to Youngsun Baek, Soyoung Park, Jungwon Yoon, Haewon Jun, Hyunju Jung and Anne for great companionship and warm support.

Finally, my greatest appreciation goes to my parents. Their unconditional and unchanging love has been the greatest backup for me. Also, my dearest little sister, Yeona, has always been the source of joy for me. Seunghyun Hwang, my husband, best friend and awesome research assistant, has been one of the greatest supporters in finishing this dissertation and he will be so forever and ever in my life. Also, I want to express my deepest love to Seoyoon, my baby who has been living with my dissertation since her day one. Last but not least, I would like to thank and give all the glory to God.

October 2013
Yeonji No

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

This study examines the relationship between an inventor's motives and creativity, invention commercialization, and collaboration pattern. Special emphasis is placed on the educational background of inventors when examining the effect of inventor motive on invention commercialization. The data are based on a unique survey of patent inventors in the United States, and archival data. The GT/RIETI 2007 Inventor Survey includes information on commercialization for patented inventions and measures of inventor motives. Archival data based on Lai et al. (2011) was the basis for the collection of creativity measures based on U.S. patent technology subclasses.

The results indicate that inventors' motives differentiate the outcome of innovative activities. We found a firm motive has a positive effect on creating new combinations, commercialization of patents, and collaboration with coworkers. The results also suggest that the recognition motive negatively affects the creation of new combinations, and that there is no effect on the commercialization of the patent. As for collaboration pattern, the results show that individual differences in motives are associated with different patterns in collaboration. For example, task-oriented inventors are less likely to collaborate with others outside of the firm entity, whereas inventors with recognition motives are more likely to have a larger collaborative network with other professionals in the same field.

This dissertation suggests that policy-makers should consider individual heterogeneity in innovative performance, knowledge creation, and patterns of collaboration. Based on the findings, future research and policy implications are discussed.

CHAPTER 1. INTRODUCTION

1.1 Introduction

Innovation is a key source of competitive advantage. Fagerberg, Mowery and Nelson (2004) defined innovation as the first attempt to put a new product or process into practice, and innovation is generally recognized to be the combination of invention and commercialization [or, putting into practice] (Afuah, 2003; Roberts, 1988). Schumpeter emphasized this point by asserting that invention "does not necessarily induce innovation, but produces of itself … no economically relevant effect at all" (1942). Ever since Schumpeter, innovation has played increasingly important roles in both national and industrial competitiveness (Cantwell, 2005). Along with the global trend toward a knowledge-based economy and globalized competition, building up innovation capabilities is taking the central place in the agendas of policy-makers as well as firms.

Academic discourse relating to innovation began in the 1950s by economists such as Schmookler (1962), Griliches (1957), Nelson (1959), and Arrow (1962). They argued that innovation is the production of new information, and that it implies increasing returns within the firm because innovation creates natural monopolies in the market. Therefore, firms invest in innovation to generate more profit, and this behavior could affect the rate and direction of technological change. However, innovation also often has characteristics such as non-rivalry and non-excludability so that more than one firm can benefit from the innovation simultaneously; and this cannot be prevented.

Many researchers have examined the influence of individual and organizational factors on innovation, reflecting this growing emphasis on the role of innovation. Because of its national and industrial impact, innovation and its antecedents have also been the center of discussion for policy makers and firms. At the individual level, factors such as personality traits, affect (Amabile et al., 2005), and motivation (Amabile, 1988; Sauermann & Cohen, 2010; Sauermann & Stephan, 2010) have been discussed. Also, many organizational antecedents have been explored, such as collaboration (Bikard & Murray, 2010; Fleming, Mingo & Chen, 2007; Singh & Fleming, 2010), network (Perry-Smith & Shalley, 2003) and types of organization (Damanpour, 1991).

We can measure innovation in a variety of ways. Patents have been one of the most widely used indicators due to their accessibility, well-established archive and objectivity (Sauermann & Cohen, 2010; Schmookler, 1954). Simultaneously, creativity has been the center of the discussion among policy-makers and firms, because creativity brings new ideas to the field and leads to innovation. Creative work is defined to be novel and useful (Amabile, 1996; Stein, 1963), and some argue that novelty is based on new combinations (Simonton, 1999). Its creation may be individualistic, but its usefulness is socially defined (Csikszentmihalyi, 1999; Gardner, 1993; Simonton, 1999), and therefore, idea generation and its usefulness should be understood separately (Osborn, 1957). This dissertation focuses on the "novelty" of invention in Chapter 4, and the "usefulness" of invention in Chapter 5.

In terms of organizational context affecting innovation, many studies have tried to understand collaborative work, as collaboration has been adopted rapidly and emphasized in both the academy and firms (Adler, Kwon & Heckscher, 2008; DiMaggio, 2003; Wuchty, Jones & Uzzi, 2007). Even if some found weak influence of collaboration on productivity in scientific research (Lee & Bozeman, 2005) and communication problems in collaboration (Dougherty, 1992), many articles have emphasized the positive effect of the collaboration. For example, von Hippel (2005) suggested the possible democratizing effect of collaboration, and some have argued that collaboration increases creativity by creating opportunities for technology brokerage based on diversity in the group (Burt, 2004; Fleming, Mingo & Chen, 2007; Hargadon, 2003; Hong & Page, 2004; Leonard-Barton & Swap, 1999; Singh & Fleming, 2010). Despite the ample discussion of collaboration and its impact on innovative output, there is a lack of research relating collaboration to individual characteristics such as motives. Some (Beaver & Rosen, 1978; Fox & Faver, 1984; Lee & Bozeman, 2005; Melin, 2000) have suggested motivations for collaboration (i.e. complementing skills and knowledge), but spoke more about the reasons for conducting collaboration, than about personal traits that lead to collaborative work.

In this project, we aimed to understand individual antecedents of innovative performances, measured by creativity and commercialization of the patent. We also investigated how individual factors such as motive influence collaborative behavior. Understanding individual motives behind innovative performances and collaboration, especially in terms of patented invention, contributes to the discussion of technology policies. The patent system has long been implemented as an important policy instrument used to stimulate innovation. By publicly disclosing "novel," "useful," and "nonobvious" invention, the inventor receives exclusive rights to exploit that patented invention for a fixed period of time. It creates a favorable environment where R&D investments can be recovered, and inventors are expected to use more of their resources toward R&D than elsewhere (Hall & Ziedonis, 2001). Based on this fundamental mechanism, we expect disclosed information on inventions to be appropriated in order to actually fulfill its purpose to the innovation. Nonetheless, there are many unused patents available, calling for recent discussion on “sleeping patents” (Arya & Mittendorf, 2004; Jung, 2009). Even though we acknowledge that some patents are unused strategically (see Jung, 2009), many countries around the world have implemented policies in order to stimulate commercialization of the patent. For example, U.K. recently (April, 2013) introduced a policy called “the Patent Box”, which allows companies to apply for a lower rate of corporation tax on profits from exploiting patented inventions.[1] As opposed to other tax initiatives provided that relate to R&D activities, the Patent Box policy is specifically aimed toward fostering commercialization of the invention while recognizing the

[1] http://www.hmrc.gov.uk/ct/forms-rates/claims/patent-box.htm

problems of unused patents. That being said, this dissertation could expand our understanding of underlying mechanisms, from the invention to the commercialization of the patents, through the examination of individuals' motives for wanting more creative patents and wanting more commercialization of inventions. Moreover, it contributes to the discussion of R&D management in understanding productive R&D employees, and to the implication thereof.

1.2 Research Questions

Differentiating innovation by its uses and novelty, and perceiving individual antecedents will help us to gain a holistic understanding of innovation. This dissertation aligns with the effort of examining factors influencing innovation at both the individual and organizational levels. This study used both direct and indirect measures of innovation activities (created from multiple information sources including patent bibliometrics, firm and industry databases), and a large-scale inventor survey. Based on this novel dataset, this dissertation aims to answer the relationship between motives and creativity with a focus on patent originality; the effects of motives on patent usefulness (measured by invention commercialization); and lastly, how motives affect collaboration patterns. Grounded on previous literature, motive is understood with 4 different types (task, pecuniary, recognition and firm motives). The research question is illustrated as a diagram in Figure 1.1.

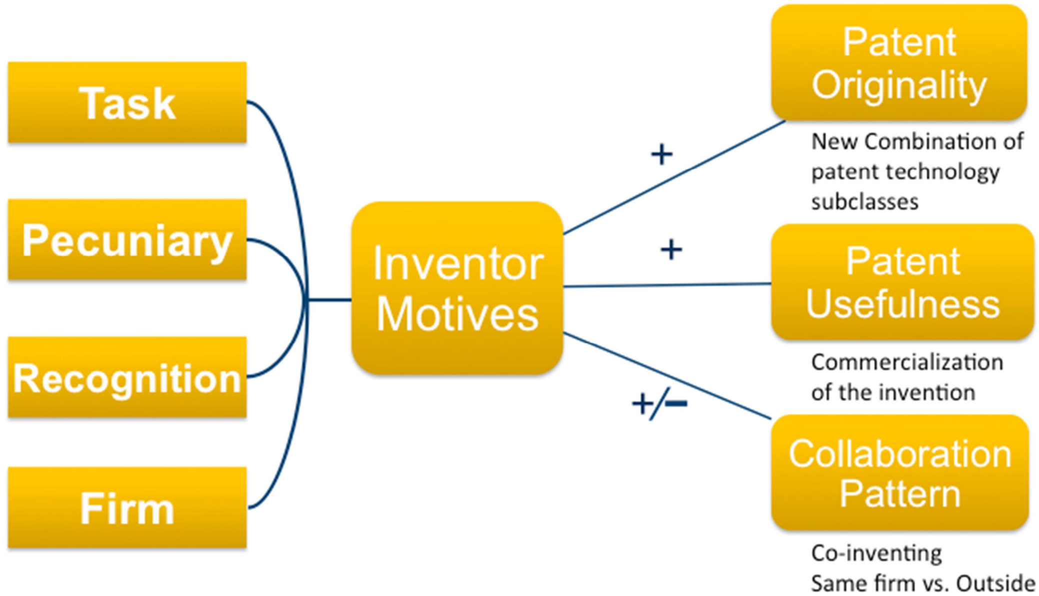


Figure 1.1 Research Questions

First, we looked at the effect of motive on the novelty side of invention. In addition to the GT/REITI Inventor Survey data, we created a recombination measure based on the data of Lai et al. (2011). They have collected patent document information including U.S. Patent Subclass (USPC). We paired technology subclasses to see if any new combinations appeared in the GT/RIETI Inventor Survey sample compared to the earlier patent stock. This analysis examined the patent originality as a function of motives. In this section, we expected that new combinations would be positively associated by inventors with all types of motives, except the recognition motive. Considering the risk associated with being original, inventors with recognition are expected to be more apprehensive toward creativity.

Next, we investigated how motives influence patent usefulness, measured by commercialization of the invention. Commercialization includes establishing a start-up company, licensing, cross licensing and commercializing the patent in the firm where the patent is filed (detailed discussion about measures is provided below). Also in this chapter, we examined if educational background moderates the effect of motives on the same dependent variable. It is hypothesized that all motives are positively associated with the commercialization of the invention. Also, the impact of recognition motive on commercialization would be stronger for basic research as opposed to applied research. Likewise, I hypothesized that the impact of firm motive on commercialization is stronger for applied research than for basic research.

The last chapter of this dissertation surveys the effect of motives on collaboration. Collaboration is measured in various ways using the GT Inventor survey instruments. Among them, this dissertation uses information about the organizational affiliation of co-inventors (such as the same firm where respondents belong, suppliers, customers, etc.) Comparing patents created by solo-inventors, internal co-inventors and external co-inventors, this dissertation is expected to illustrate an in-depth understanding of collaboration patterns and inventor motives. Given the trait-like characteristics of motive, we expect that the task motive will decrease collaborative activities. Also, researchers with recognition motives are expected to have larger collaborative networks, particularly as their experience increases. In general, inventors with recognition motive are expected to seek more outside collaboration in order to make a name for themselves. Also, in consideration of the Matthew Effect (Merton, 1968), the size of the collaborative network is expected to expand. As for inventors with a firm motive, we expect that they would collaborate exclusively with researchers within the same firm.

1.3 Dissertation Structure

This dissertation consists of seven chapters. The next chapter discusses previous literature and develops the hypotheses that this research intends to test. Chapter 3 describes the data, measures and analytical strategies used in the research, before beginning to address research questions proposed by this research. Chapter 4 reports analyses on the relationship between motive and creativeness of the invention, and Chapter 5 examines the impact of motive on the commercialization of the invention, and whether the impact is different between scientists and engineers. Subsequently, Chapter 6 analyzes how motive affects collaboration pattern. Last, Chapter 7 concludes with the result summaries, research limitations, and policy implications.

1.4 Summary of Findings

As described in Table 1.1, we have found that inventors' with task, pecuniary and firm motives have a positive association with invention creativity and commercialization. However, inventors' with recognition motives are negatively associated with invention creativity, and have no significant effect on commercialization. We have not found a significant moderating effect of educational background on the relationship between motive and commercialization of the patent. As to collaboration, the result suggests that inventors with firm motives are only positively associated with same-firm co-invention, as opposed to external co-invention. Task motivated inventors are found to have negative associations with co-inventing, which suggest that they are more likely to work by themselves. For inventors with recognition motives, we have found that more senior inventors are more likely to engage in larger collaborations.

Table 1.1 Summary of Findings

Dependent Variable		Hypothesis	Result
Creativity	HP1	Task ↑ New combinations	Positive, but Not Significant
	HP2	Pecuniary ↑ New combinations	Positive, but Not Significant
	HP3	Recognition ↓ New combinations	Negative
	HP4	Firm ↑ New combinations	Positive, but Not Significant
Commercialization	HP A	Task ↑ Innovative performance	Positive
	HP B	Pecuniary ↑ Innovative performance	Positive
	HP C	Recognition ↑ Innovative performance	Not Significant
	HP D	Firm ↑ Innovative performance	Positive
	HP E	Recognition × Scientists > Recognition × Engineers on Innovative performance	Not Significant
	HP F	Firm × Engineers > Firm × Scientists on Innovative performance	Not Significant
Collaboration	HP I	Task ↓ Collaborative activities	Negative
	HP II	Pecuniary has No-Significant relationship with the Collaborative activities	Not Significant but positive on external co-inventors
	HP III	Recognition ↑ Collaborative activities	Positive only on the number of external co-inventors
	HP III-A	Recognition × Tenure ↑ Collaborative activities	Positive
	HP IV	Firm ↑ Collaborative activities	Not Significant
	HP IV-A	Firm ↑ Internal collaboration, rather than External collaboration	Positive

CHAPTER 2. LITERATURE REVIEW

In this section, previous literature on the individual motive, creativity and collaboration is summarized. In the next sections I introduce tested hypotheses. This literature review is particularly focused on individual motives, and their effect on innovation, creativity and collaboration. This dissertation first explicates individual motives to describe the main theme of the research, and then reviews the effect of individual motives on creativity, as well as on commercialization. The next section discusses collaboration and its relation to individual motives.

2.1 Individual Motives

This study focuses on individual motives as major individual antecedents. The importance of the individual in innovative activities has long been featured across disciplines. The Sociology and Economics of Science have researched how individual motives such as recognition and intellectual challenge affect the advance of science (Dasgupta & David, 1994; Merton, 1973b; Stephan, 1996; Stephan & Levin, 1992; Zuckerman, 1988). Understanding the responsibility that firms have to innovate, particularly toward commercialization, economists have also paid attention to firms' incentive systems, which encourage individuals' innovative performance. Schumpeter

(1934; 1942), for example, suggests that individuals' incentives are critical for entrepreneurship and innovative activity.

Prior work on motivation and motives has generally been focused on two key dimensions: intrinsic and extrinsic motivations (Amabile, 1996; Amabile et al., 1994; Gagne & Deci, 2005; Ryan & Deci, 2000; Sauermann, 2005; Sauermann & Cohen, 2010; Sauermann & Stephan, 2010). In Self-Determination Theory (SDT; Deci & Ryan, 1985), the most basic distinction between intrinsic and extrinsic motivations is illustrated. Intrinsic motivation refers to doing something because it satisfies innate psychological needs such as competence, autonomy, and relatedness, while extrinsic motivation refers to doing something because it leads to a separable outcome. Ryan and Deci (2000) argued that extrinsic motivation can vary greatly upon the degree to which it is autonomous. Even though the task might not be intrinsically interesting, they argue that individuals can self-regulate such activities through internalization and integration so that individuals can implement activities without external pressure. They presented a taxonomy of human motivation describing four different types of extrinsic motivation:

1. External regulation is the least autonomous form of extrinsic motivation. It is performed to satisfy external demand or reward.

2. Introjection is a type of internal regulation with external contingencies. Ryan and Deci described that individuals carry out such behavior with the “feeling of pressure

in order to avoid guilt or anxiety or to attain ego-enhancements or pride" (2000, p. 62).

3. Identification is a more autonomous form of extrinsic motivation. An individual has identified with the activity and accepted associated regulations as their own.

4. Integration is the most autonomous form of extrinsic behavior, and takes place when identified regulation is fully assimilated with the self. Individuals accord the given regulation with their values and needs.

In addition to this intrinsic and extrinsic dichotomy, previous literature has incorporated recognition in describing motives. Stephan and Levin (1992) distinguished three: "puzzle," "gold" and "ribbon," which respectively stand for intrinsic, extrinsic, and recognition. Walsh and Tseng (1998) later explicated recognition in terms of social rewards. However, in order to address the different motives of inventors particularly in industry, this study expanded the motive groups to four dimensions: task, pecuniary, recognition, and firm, and tested the effect of motives on innovative performances. Based on Ryan and Deci's taxonomy of human motivation, and types of extrinsic motivation, we illustrate in Figure 2.1 how motives are classified in this dissertation. Moreover, in the following chapter, we will describe how this classification fits into our data through explicating the result of factor analysis.

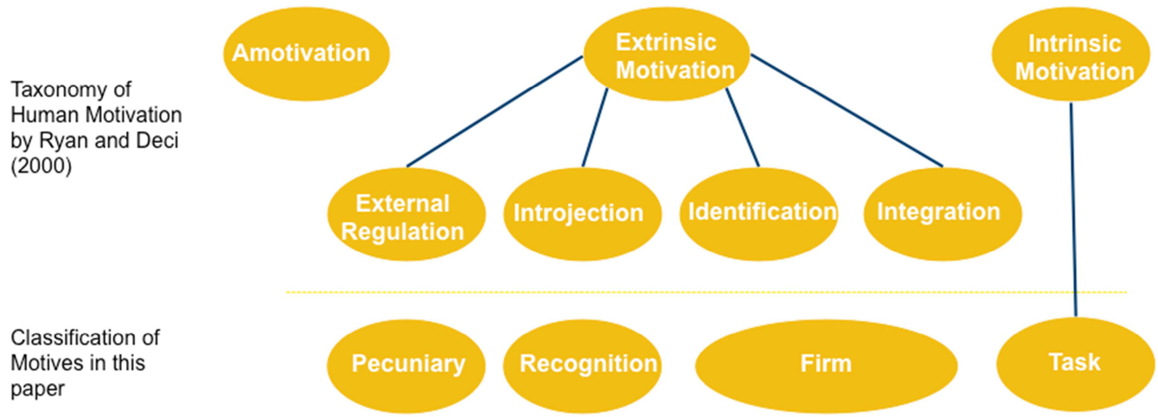


Figure 2.1 Typology of Motives

Task Motive is associated with the individual and the activity itself. It is also associated with the intellectual challenge and associated satisfaction from "solving puzzles" (Sauermann & Stephan, 2010; Stephan & Levin, 1992). Achievement, enjoyment, and intellectual challenge are examples of the task motive. In psychology, it is framed around "intrinsic" motivation, and scientists are shown to have higher research performance when "intrinsically motivated" (Amabile, 1996; Ryan & Deci, 2000). In this project, task motive is considered an extension of intrinsic motivation based on Ryan and Deci's taxonomy (2000), since individuals satisfy their needs by the activity itself.

Amabile (1996) and Stephan (1996) indicated that some task motivations, such as intellectual challenge and enjoyment of the task, are realized when individuals are involved in the activity. Other types of task motive, such as achievement or self-competence, originate from task performance and outcome. In psychology, highly educated knowledge workers (e.g. researchers) are likely to be intrinsically motivated to engage in research activities and find themselves content with the activity itself (Amabile, 1996; Ryan & Deci, 2000). Previous research suggests that task motive is associated with the amount of effort researchers invest in research (Levin & Stephan, 1991; Sauermann & Cohen, 2010) and has a positive effect on the productivity of industrial scientists (Sauermann & Cohen, 2010). Empirically, Stern (2004) claimed that industrial scientists should have a “taste for science”—strong orientation toward research-oriented careers. Stressing preference toward solving puzzles and completing tasks, he showed that new biology PhDs prefer to work in firms where they are allowed to engage in more academic activities, such as publishing and taking part in scientific conferences, at the cost of a lower salary. His research concluded that these researchers have a “taste for science” and are task motivated.

Pecuniary Motive originates from environments such as markets, employers, or customers, and satisfaction of the motive is usually conditional upon the assessment of the task outcome. According to Ryan and Deci’s taxonomy (2000), this is considered to be the least autonomous form of extrinsic motivation, and they labeled it as an external regulation. Economists and social psychologists often measure pecuniary motive using monetary rewards, given that it is one of the most prevalent forms of external motivating factors. A positive relationship between financial incentives and work performance has a long tradition in theories of motivation. For example, Vroom’s Expectancy Theory (Vroom, 1964), which proposed that the desirability of the outcome determines how individuals behave, expects that individuals choose to act in favor of “pecuniary” because financial incentive is valuable. In turn, pecuniary incentives were perceived to increase work performance. Also, based on incentive theory (Lawler, 1971), Jenkins et al. (1998) summarized in their meta-analysis that high pay would engender high performance, and performance is reinforced and repeated. Moreover, a laboratory experiment by Camerer and Hogarth (1999) suggested that individuals' cognition, memory, recall, and simple problem-solving functions have been improved by pecuniary rewards.

Recognition Motive is defined as motivation toward receiving a ribbon, award, or other form of recognition or boost to reputation. It is contingent upon social context and is not associated with the task attributes. In the Hawthorne study, Mayo and colleagues claimed that employees have generated higher productivity when they were given attention and properly acknowledged by their supervisor (Mayo, 1945). Their findings signify the importance of recognition, and tell us that mere monetary rewards are not sufficient for increasing productivity among individuals who are recognition-motivated (Bendix, 1974; Walsh & Tseng, 1998). According to Pelz (1976), "recognition is a basic sense of awareness and appreciation rather than monetary reward" (p. 331). Examples of the recognition motive include forms of social approval, peer recognition, or a more formally institutionalized system such as an award. It has been claimed that recognition motive is one of the most important factors in determining whether and how the research result is disclosed (Haeussler et al., 2009; Mukhergee & Stern, 2009). In addition, according to West and Farr (1989; 1989), the degree of support from others (such as peers and superiors in work settings) is one of the more important factors for generating innovation.

Support can take many forms, from physical resources to positive feedback, all of which encourage attempts to be innovative (Farr & Ford, 1990).

In the context of research, individuals are faced with the judgment of others, especially when disclosing the research (either through publication or invention disclosure). When an invention is proven to be novel, the only ones recognized are the people that first invent/introduce it to the scientific community (Merton, 1973a; Merton, 1973b). Even though there is a difference between priority rights and proprietary rights,[2] they share similarities such as the fact that being first matters. Since Merton (1973b), it has been argued that there are rewards to priority—the endowment of credit for intellectual priority and property rights, establishment of reputation, and creation of opportunities for involvement with prestigious institutions, granting access to resources for future research (Stephan, 2010). For example, Shuji Nakamura has been recognized for his invention of the blue LED during his employment at Nichia. His invention led him to establish his reputation in the field with a number of awards, as well as a job at the University of California, Santa Barbara. Likewise, by disclosing inventions with their name attached, industry researchers can be recognized as being first, especially when the firm does not allow publication. Numerous industry researchers have received top honors in their field, and firms like Bell Lab, DuPont, and IBM have housed top awards such as the Nobel

[2] See Stephan (2010).

Prize. Stern (2004) evidenced that industry researchers sacrifice their monetary reward in the interest of receiving recognition from the field through publishing their research output. Moreover, because the nature of research renders feedback from others inevitable, some argue that the recognition motive is one of the most important factors in determining whether and how the research result is disclosed (Haeussler et al., 2009; Mukhergee & Stern, 2009).

Firm Motive is contingent on identity as an organizational member. It offers people a sense of belonging, and makes people want to maintain their membership in the organization. For example, people might think it is important to work for generating value to the firm, or for being responsible. Unlike other motives that are individualistic, this is a motive focused on membership and sense of "us" as a group. Considering that the goal of the firm is accepted by an individual as their own, and could develop to be congruent with their own needs and values, we argue that firm motive could be classified between identification and integration in Ryan and Deci's taxonomy of human motivation. In other words, firm motive is rooted in external value that is separate from the activity itself; yet it leads the behavior to be volitional and integrated by one's self.

Even though it is not dealt with much in the motivation literature, many studies from Social Psychology discussed a similar concept and labeled it as "Organizational Commitment" or "Organizational Identification." Both of these concepts resonate with each other in the sense that they emphasize the attachment one has to the organization. Organizational commitment was defined by Mowday, Steers and Porter (1979) as "the relative strength of an individual’s identification with and involvement in a particular organization.” Furthermore, they characterized organizational commitment as “1) a strong belief in and acceptance of the organization’s goal and values; 2) a willingness to exert considerable effort on behalf of the organization; 3) a strong desire to maintain membership in the organization” (p.226). Later, Meyer and Allen (1991) defined three components of Organizational Commitment, or OC, as having an “emotional attachment to, identification with, and involvement in, the organization.” While Organizational Identification, or OI, has its roots in social identity theory, it is defined as “the perception of one-ness or belongingness to some human aggregate” (Ashforth & Mael, 1989).

To better understand OC and OI, we compare and contrast the explicated characteristics of each orientation, as summarized in Table 2.1. Unlike OI, which is focused on self-definition via organizational membership (Mael & Ashforth, 1995; Pratt, 1998; van Knippenberg & Sleebos, 2006), OC considers the organization and the self as separate entities (Ashforth, Harrison & Corley, 2008).

Table 2.1. Organizational Commitment and Organizational Identification

Organizational Commitment	Organizational Identification
Positive attitude toward organization: Self and organization remain separate entities	Emphasis on self-definition via organizational membership: Perceived one-ness with the organization
How happy or satisfied am I with the organization?	How do I perceive myself in relation with the organization?
Transferrable to other organization	Organization specific
Associated with attitudinal variables like job satisfaction	Associated with attractive, distinctive, internally consistent organizational identity (e.g. shared fate of organization, antipathy toward the rival organization, and self-sacrifice on behalf of the organization)
	Can be associated with negative emotional experience

Source: (Ashforth, Harrison & Corley, 2008)

Empirically, different measures are associated with OC and OI so they can be distinguished (even though they often can be correlated). Riketta (2005) and others (van Knippenberg & Sleebos, 2006) have reported that OC is found to be associated with attitudinal variables such as job satisfaction, while OI is found to be related to variables that are distinctly described by the organizational identity, such as antipathy toward rival organizations and self-sacrifice for the organization (Ashforth, Harrison & Corley, 2008; Pratt, 1998; van Knippenberg & Sleebos, 2006). Also, a study by Herrbach (2006) reported that OI was associated with negative emotional experiences. At first, OI had a positive effect on emotional experience, but this association disappeared once OC was introduced into the model.

Based on their differences, we consider OC to be a better fit with firm motive than OI. As described above, Mowday, Steers and Porter (1979) claim that OC is operationalized as acceptance of the goals of the organization, working hard for the organization, and, in particular, having a strong desire to keep organizational membership. Moreover, questions asked in the survey conducted and analyzed for this dissertation had no assumption of oneness between the individual and the organization.

Relating attitudinal organizational commitment to motivations, Meyer and his colleague claimed that organizational commitment resonates with motivational processes explicated in Self-Determination Theory (Meyer, Becker & Vandenberghe, 2004; Meyer & Maltin, 2010). In particular, affective OC is considered to be close to autonomous forms of regulation, as opposed to controlled forms of regulation. Empirically, based on a survey of Italian automotive employees, Gagne et al. (2008) found partial support of this hypothesis, in that affective OC is more strongly related to measures of autonomous regulations than to measures of introjected and external regulations. Therefore, Meyer proposed that both motivations and commitment mindsets are related, in the sense that they are conditions influencing psychological satisfaction of the needs for autonomy, competence and relatedness in the work context.

Previous studies have extensively analyzed the relationship between organizational commitment and work outcomes such as job performance. In addition to meta-analyses that reported positive relationships between affective OC and work performance (Mathieu & Zajac, 1990; Meyer et al., 2002; Randall, Fedor & Longenecker, 1990;

Riketta, 2002; Wright & Bonett, 2002), empirical studies have asserted that individuals with higher levels of organizational commitment perform better (Hunter & Thatcher, 2007; Morin et al., 2011; Vandenberghe, Bentein & Stinglhamber, 2004).

Because of the implications of the concept of OC and its relevance to our research, we would like to expand the discussion about the motives and their related outputs beyond the three more widely studied pecuniary, recognition, and task motives to include firm motive as a driver of innovation and collaboration.

2.1.1 Motives as Traits

In this dissertation, we use the term “motive” instead of “motivation.” Compared to motivation, which is framed around task, motive may be a more appropriate term, given that it connotes a trait-like characteristic (Sauermann & Cohen, 2010). Amabile et al. (1994) discussed motivational orientations being considered as personal traits to a certain extent, and signified that motives are a relatively stable and enduring individual characteristic across time and situation. Deci and Ryan (1985) developed measures of personal causation orientation, which is trait-like. Even though it concerned people’s causation, their argument resonates with intrinsic and extrinsic motives. For example, they suggested that autonomy-oriented people are more likely to be intrinsically motivated, while control-oriented individuals are extrinsically motivated. The research proposed that people’s causation process is contingent on their situation, needs, emotions, and cognition. Based on the reliability test conducted over a two-month period, they reported that this motivational orientation can be regarded as a personal disposition.

Similarly, Kanfer et al. (Kanfer & Ackerman 2000; Kanfer & Heggestad 1997; Kanfer & Heggestad, 1999) theorized about and tested motivational traits. Based on the assumption that relatively stable motivational traits affect how individuals perform in the work setting, they found that individual traits such as achievement and anxiety are reflected in work motivation. For example, Kanfer and Ackerman (2000) found evidences that achievement is related to individuals' motive for desire to learn and task improvement.

As such, we can think of motives as stable personal characteristics. In this manner, this research aims to distinguish between motive and incentives/rewards. Following operant theory (Skinner, 1953), rewards are commonly believed to promote all behaviors (including organizational goals) by enhancing the motivation and satisfaction of individual employees. With this tradition, previous studies from Economics and Social Psychology have implicitly assumed direct correspondence between individual motivation and a reward system. Accordingly, previous studies on incentives were focused on improving reward utility experienced by individuals (Chen, Ford & Farris, 1999). On the other hand, based on learning theory (Hull, 1943), others assumed that all behaviors were derived from psychological drives rather than from rewards. For example, under the influence of learning theory, intrinsically motivated activities offer satisfaction of psychological needs rather than rewards, e.g. the activity itself (Ryan & Deci, 2000). This dissertation is grounded in the second approach, wherein individual activities are carried out to satisfy their innate needs.

Extrinsic motivation, or the pecuniary motive, has been widely matched with extrinsic reward, while intrinsic motivation, or the task motive, has not been equated with incentives particularly due to its difficulty in analysis and control (Williamson, 1985). Problems arise when assuming there is a direct correspondence between motivation and reward. One of the problems is that rewards may not motivate employees and benefit organizations, as they were initially intended to. For example, an extrinsic reward that was given to employees in order to increase performance could turn out to cause negative effects, especially on their creativity (Amabile, 1988).

Given that reward is contingent upon performance, we can distinguish motive from incentive. Unlike incentive, no condition is required for individuals to have such motive, and personal characteristics are not bound by their performances. It more concerns personal disposition, and is based on psychological needs of individuals. Correspondingly, motives precede an individual’s work behavior and outcome, so that a person would choose, for example, how to approach or avoid the problem in a way that aligns with their personality. Moreover, motive and incentive are different in their stability. As a personal disposition, a motive is a stable characteristic, while incentive is volatile, as it changes upon the established condition.

However, this research is limited in that many studies referenced in this dissertation also assumed direct correspondence between reward and motive. Even though this dissertation is based on those articles, we want to clarify that we do not, and cannot, test incentives in this research. Rather, based on our data and assumption that motive is trait-like, we focus on testing the effect of motives. In this way, we can contribute to the understanding of other types of motive.

2.2 Creativity

The concept of creativity at work represents generating new ideas or work processes, by either coming up with entirely innovative thoughts or recombining existing approaches in novel ways. Usually, creativity is defined as “an approach to work that leads to the generation of novel and appropriate ideas, processes, or solutions” (Perry-Smith & Shalley, 2003). This means that creativity does not have to take place only in certain units of the work place (for example, R&D); rather, it can happen wherever an individual performs their work, including the manufacturing and sales divisions. Regardless of location, it is more important that the output should entail some degree of uniqueness, but should be understood by others in order to be adopted and implemented. In other words, creativity is framed around novelty and its usefulness, whereas productivity focuses on the quantity of the output (Amabile et al., 1996; Fleming, Mingo & Chen, 2007; Oldham & Cummings, 1996). These distinctive features of creativity go back to the pioneering work by Stein (1953). He suggested that creative work is a “deviation from the traditional or the status quo” and that the community should validate the usefulness of the work. This is reiterated by Simonton (1999), that novelty is first screened by an individual’s cognitive process, and then selected again through discussion with the peer intellectual community.

Creativity is also understood in a continuum based on its degree (Amabile, 1996; Perry-Smith & Shalley, 2003; Shalley, 1995). Relative to its level, we can distinguish creativity between minor and major contribution (Mumford & Gustafson, 1988). A major contribution, for example, could be a technological breakthrough that changes the approach to a problem, and therefore has a great impact in the field. On the other hand, a minor contribution could be the recombination and adjustment of existing principles. In this article, the term "creativity" does not differentiate between major and minor contributions. Rather, it embraces all degrees of creativity, not focusing on the tail end of its distribution.

In his seminal work, Schumpeter stated that "innovation combines components in a new way, or that it consists in carrying out new combinations" (1939). Understanding innovation as a process by which inventors create new technology, Nelson and Winter claim that recombining any existing conceptual and physical material is critical in the production of novel science and art (1982). Henderson and Clark (1990) also argued that technological breakthroughs can be created by the rearrangement of previously used components. Kogut and Zander (1992) introduced the term "Combinative Capabilities" to signify the ability to synthesize and apply acquired knowledge. They claimed, "innovations, are products of a firm's combinative capability to generate new applications from existing knowledge" (p. 391). Here, Combinative Capability means the intersection of capability to exploit both knowledge and technical opportunity. Using the case study of Hertz, who developed modern wireless telephony, Levinthal (1998) also argued that the application of existing technology is critical to exploring new paths of application. Creative technology stems from the rich soil of existing resources, and could become “creative destruction” when dispersed to other niches.

The ability to combine existing components is, however, limited. Because inventors and their teams pick what is thought to be relevant and significant, combining existing technology is bound by inventors’ experience and knowledge (Fleming, 2001). Consequently, the recombination process needs to be understood in relation to the individual. In fact, examining the relationship between individuals and their outcomes has been one of the most important topics in the study of innovation (Griliches, 1957; Gruber, Harhoff & Hoisl, 2012; Harhoff et al., 1999; Schumpeter, 1934; Stephan, 1996), which vary from inventor productivity (Zucker & Darby, 1996) to collaborations and network (Allen, 1977; Fleming, Mingo & Chen, 2007). Also, given that human resources are the core of constructing knowledge, and all resources, skills and knowledge are put together to create technological recombination, previous literatures discuss the individual differences and their effect on knowledge recombination (Gruber, Harhoff & Hoisl, 2012; Kogut & Zander, 1992). However, there are limited studies that investigate knowledge recombination at the individual level. Studies on micro-foundations (Felin & Foss, 2005; Felin & Hesterly, 2007; Rothaermel & Hess, 2007) have called our attention to considering the “individual” as a way to explain the process of building the dynamic capability of the firm. Felin and Foss (2007) pointed out that current literature on strategic organizations mostly consider the “organization” without incorporating the individual. For them, this finding means that current literature does not assume the heterogeneity of the individual, who comprises the organization, and of the interaction between the two different levels. Therefore, they stressed the micro-foundation, which is defined as the individual-level heterogeneity that precedes the collective phenomena. Rothaermel and Hess (2007) empirically argued that, indeed, the innovation lies across different levels: individual, firm and network-level.

Andrews (1979) claimed that individuals' creative ability is reasonably stable, even though it may show short-term volatility. Stable and continuous trait-like personal characteristics have since been studied in relation to creativity. Simonton (1999) narrated the relationship between personal traits and individuals' performances. Assuming that scientific theorizing needs combinatorial thoughts and trials, Simonton asserted that creative individuals have particular inclinations to pursue combinatorial research. In addition to the personal disposition, Fleming et al. (2007) indicated that several individual-level factors, such as boundary-spanning inventor's cohesive networks and experience are critical in producing new combinations of subclasses in invention. Recently, Gruber et al. (2012) showed the importance of educational training in combining technology boundaries. They reported that higher education (PhDs) and degrees in science are more likely to generate technological recombination. Borrowing literature from creativity and the economics of science, which also can be understood in terms of recombination (Hargadon, 2008; Hargadon & Sutton, 1997), Sauermann and Cohen (2010) have studied how individual motives affect inventor productivity.

Previous studies on motivation and creativity have discussed that intrinsic (task) motive is a critical driver of creativity (Amabile, 1983; Elsbach & Hargadon, 2006). Shalley et al. (2004) reported that task motive increases creativity by stimulating positive affect, cognitive flexibility, risk taking, and persistence. Recently, however, it has been questioned as to whether the sole effect of intrinsic motivation on creativity has been taken into consideration, as have other factors such as network (Perry-Smith, 2006; Shalley & Perry-Smith, 2001). Pursuing in-depth understanding of the relationship between motivations and creativity, Grant and his colleagues (2011; 2008) have claimed that prosocial motive—the desire to help others—has a moderating effect on the relationship between intrinsic motive and creativity. In this dissertation, we would like to examine creativity—defined as technology recombination—based on creativity literature and sociology of science on individual motives and their effect. In particular, this study aims to expand the discussion by introducing other motives, such as firm motive, and examining the interaction effect.

As noted above, it has long been discussed that intrinsic motivation is an important factor for creativity. Based on close examination of 115 scientists, Andrews (1979) asserted that creative people need to have freedom in order to show their innovativeness. Under autonomous working conditions, industrial scientists and engineers are believed to give their best in order to fulfill their intrinsic motive toward solving puzzles or completing tasks. Moreover, Amabile and colleagues argue that an individual's inherent drive in solving problems is required in order to be creative (Amabile, 1983; Barron & Harrington, 1981). Trying to understand the mechanism behind the relationship between the intrinsic motive and creativity, it has been suggested that a task motive broadens the range of information (expanding the scope of attention to the wider set of ideas) and increases the cognitive ability to identify combinatory elements (Amabile et al., 2005). Moreover, employees' task motives help individuals increase their willingness to take risks, their openness to complexity (Gagne & Deci, 2005), their work effort (Fredrickson, 1998; Levin & Stephan, 1991; Sauermann & Cohen, 2010), and their perseverance at times of challenge, and enables them to continue working (Amabile, 1996; Shalley & Oldham, 1997). This in turn enhances individuals' access to new ideas and possible solutions, as well as ability to concentrate on the task more effectively (e.g., Amabile, 1996).

However, we found that empirical findings are somewhat mixed. In particular, studies of employees in organizations questioned whether intrinsic motivation enhances creativity, as opposed to laboratory studies that examined students' creativity (for review, see Grant and Berry, 2011). Furthermore, studies focused on R&D personnel have provided conflicting results. Based on field study, Dewett (2007) reported that an employee's self-reported creativity is positively associated with the task motive, whereas a supervisor's rating of creativity is not. Perry-Smith (2006) also found no significant relationship between intrinsic motivation and creativity, measured by a supervisor's rating of an employee's creativity. On the other hand, Shin and Zhou (2003) showed that the presence of intrinsic motivation predicted high levels of creativity in Korean employees, and

Tierney, Farmer and Graen (1999) evidenced a positive relationship between an employee's intrinsic motivation and their supervisor's rating of creativity.

Nonetheless, note that creativity, primarily measured by novelty and originality (e.g. creating artwork or poetry), is reported to be positively associated with the task motive (Amabile, 1985; Amabile, Hennessey & Grossman, 1986). Tasks in the R&D setting involve a stronger usefulness component, so that what is measured under the name of creativity should distinguish between novelty and usefulness. Based on this difference, Grant and Berry (2011) claimed that intrinsic motivation is a critical driver in producing novel work, but not necessarily useful ideas. In this dissertation, we try to measure novelty, rather than usefulness. Therefore, we hypothesize the relationship between the task motive and creativity is as follows:

> *Hypothesis 1: Task motives are positively associated with the creation of new combinations.*

Previous literature suggested that formal organizational extrinsic motive can be detrimental to creative behavior (Amabile, 1988; Amabile, 1996; Farr & Ford, 1990). However, Amabile later modified her stance, and suggested that some extrinsic motive can encourage creativity. She claimed that, to some extent, interaction between extrinsic and intrinsic motive could stimulate creativity. She used the term "motivational synergy" to describe when extrinsic motive helps promote intrinsic motive (Amabile, 1993). For example, an intrinsically motivated employee was found to be deeply involved in work when accompanied by pecuniary reward, which, in turn, impacted creativity. Eisenberger and Cameron (1996) evidenced that extrinsic rewards help to stimulate individual innovation implementation. Sauermann and Cohen (2010) also found that, in addition to the task motive, pecuniary motives had a significant positive effect on innovative activities engaged in by Science and Engineering professionals. Thus, while there are arguments that the pecuniary motive is associated with lower creativity, there are also arguments suggesting that it has no effect or even a positive effect on creativity.

Hypothesis 2: Pecuniary motives are positively associated with the creation of new combinations.

Many recent studies have shown that encouragement and support from their supervisor increases an employee's creativity and innovation (Oldham & Cummings, 1996; Shalley, 2008). As Mayo (1945) argued, employees are psychological beings who need attention and recognition, so much so that a simple monetary wage would not be enough to elicit an increased output. Accordingly, organizations are encouraged to be attentive and sensitive to an employee's non-tangible needs in order to maximize their commitment to the organization.

Pelz (1976) also emphasized that it is critical for researchers to have some achievement that bears their name. Being visible and recognized in the community increases exposure to new problems, stimulates curiosity, and eventually productivity. Furthermore, Andrews (1979) suggested that there are stages a scientist/researcher may put a creative idea through: the idea is internally evaluated, communicated to others, and finally, is received by others. The authenticity and novelty of the work is validated by others only after it is circulated among fellow experts in the field (Storer, 1966) assuring the research has been conducted properly, after which it can be published, disclosed, and/or patented. Fleming (2001) also stressed the importance of perception in developing novel recombinations. From many possible components, inventors come up with an idea for recombination based on their range of experience, knowledge and thoughts. Fleming argued that social construction and previous association determines if certain components “belong together.” For example, elements required for semiconductors were not previously perceived as belonging together (Fleming, 2001). Since technology evolves interdependent to existing technology, there is the matter of the right timing and environment in order for a new technology to be considered novel, rather than absurd. Abundant resources of existing components provide inventors a pool of recombination for future inventions. However, if the process/invention is not understood, it is likely to fail.

Therefore, recognition motive might prohibit individuals from introducing novel inventions. Given the possible risk of misunderstanding, and considering that ribbon motive is more likely to be dependent on social approval than other types of motive, there is the possibility of generating more conformity to the usual. Noting that creative work is socially constructed (Csikszentmihalyi, 1999; Gardner, 1993; Simonton, 1999), inventors are bound to consider how others evaluate it.[3] Consequently, for example, groupthink (Janis, 1971; 1972) might prevent inventors from being creative through self-censorship of ideas that deviate from the apparent group consensus. The society of the individual and their recognition is so important that Simonton stated there is no unrecognized genius (1999). Thus, individuals motivated by recognition would be much more perceptive and sensitive to other's appraisal, resulting in a less creative project compared to the invention made by those with other motives.

Hypothesis 3. Recognition motives are negatively associated with the creation of new combinations.

Andrews and Farris (1967) claimed that scientists' creativity increased when organizations were supportive. In particular, when mangers listened to scientists' concerns and asked for their opinions about decisions affecting them, their creativity was found to be higher. Likewise, Andrews (1979) showed that creativity increased when scientists felt more secure in their settings, e.g. stable employment. He argued that a scientist with a sense of security in their professional life stimulates effective utilization of their creative ability..

[3] Even though this dissertation is focused on creativity in terms of novelty, we cannot ignore its utility aspect since they go hand in hand.

Moreover, relating the prosocial motive and the affective organizational commitment, we postulate the positive association between creativity and firm motives. Prosocial motive is “the desire to expend effort based on a concern for helping or contributing to other people” (Grant, 2011, p.77), and Bastson et al. (2008) argue that, with the prosocial motive, employees desire to help others because they care about them, and would like to maintain their membership in a valued group. Because the prosocial motive and the affective organizational commitment share a similar sense of belonging, we can argue that those who subscribe to organizational commitment and the prosocial motive will share similar consequences at work. Empirically, the prosocial motive is reported to benefit work context through organizational citizenship behavior, and positive association with job performance (De Dreu & Nauta, 2009). Also, Grant and Berry (2011) showed that the prosocial motive strengthens creativity. Consequently, we can suggest the following hypothesis.

Hypothesis 4: Firm motives are positively associated with the creation of new combinations.

2.3 Commercialization of the Invention

In this dissertation, innovation performance is divided into the novel and useful "creativity" (Amabile, 1996; Stein, 1963). Initially, we focused on the novelty side of creativity by measuring new technology subclass combinations of the patent. In the second section of this study, we examined the effect of motives on innovation performance, which stressed the usefulness of the patent by measuring whether or not it is commercialized. Since patents require the invention to be both novel and useful (and nonobvious), they are perceived to resemble the definition of creativity as described above. However, having a patented invention does not automatically mean it is put to use. In particular, the appropriability of the patented invention has been emphasized since Schumpeter (1942) said that invention does not have any economic effect at all if it does not produce innovation. Therefore, we have proxied innovative performance by measuring whether it has been commercialized, as commercialization of the patent can definitely give us a measure of its usefulness. Focusing on the attempt to put invention into the market, in this section we investigate the relationship between individual motive and innovative performance in order to examine the usefulness of creativity.

Typically, scientists and engineers are considered to be more task-oriented than those with other vocations. The General Social Survey (GSS), for example, illustrated that members of the S&E workforce are more likely to score high on tests measuring the non-pecuniary motives of the desire for challenge at work and the need for achievements than for pecuniary motives. Moreover, the difference between task and pecuniary motive is significantly larger for the S&E workforce than for production workers (Cohen & Sauermann, 2007; General Social Survey, 2001).

Amabile and colleagues argued that creativity is strongly associated with a task-oriented motive, rather than with recognition and pecuniary motives. They argued that those who are intrinsically motivated are likely to be more exploratory, and hence task-motivated people are more productive than those motivated by pecuniary rewards or peer recognition (Amabile, 1993; Hennessey & Amabile, 1998). Based on this argument, it has been conjectured that scientists are more task-oriented, satisfied by inventing and discovering something new. Like creative artists, S&E professionals with task motive are assumed to perform better in research-related jobs. Moreover, it has been argued that R&D professionals place more value on intrinsic rewards and often believe that extrinsic rewards are counterproductive (Chen et al., 1999).

On the other hand, some have suggested that monetary rewards enhance an individual's cognitive ability to solve problems (Camerer & Hogarth, 1999). Based on 39 laboratory, experimental simulation, and field studies, Jenkins et al. (1998) have conducted meta-analysis and reported a significant positive association between high monetary reward and performance quantity, but no relationship between lower monetary rewards and performance quality. In their study of 70 leading R&D organizations, Haigh and Gladkowski (1992) found that stability in base salary has more positive impact on employee motivation than highly-leveraged incentive packages. Also, Kuvaas (2006) reported that base pay level, but not bonuses, positively affects self-reported work performance for Norwegian energy-intensive industry workers. Furthermore, he argued that the relationship is mediated by task motive, and it is especially distinctive for highly educated knowledge workers. In a similar vein, not negating the importance of the task motive, Sauermann and Cohen (2010) found that both the task and pecuniary motives had a significant positive effect on innovative activities for doctorate recipients, graduate students, and recent college graduates from science and engineering fields engaged in basic or applied research. Likewise, Chen et al. (1999) found that providing employees both the autonomy to solve puzzles and financial stability can generate the best productivity. However, the effect of pecuniary incentives can vary depending on the task and capabilities of the individual. Previous literature suggested that formal organizational rewards may inhibit creative behavior (Amabile, 1988; Amabile, 1996; Farr & Ford, 1990). Farr and Ford (1990) claimed that reward structures based on relatively long-term perspectives may "at least not inhibit" an individual's innovative behavior. For the reasons discussed above in relation to the task motive and pecuniary motive, we offer the following hypotheses:

> *Hypothesis A: Task motives are positively associated with commercialization of the invention.*

> *Hypothesis B: Pecuniary motives are positively associated with commercialization of the invention.*

Merton (1973b) suggested that, in addition to a strong task motive, scientists are motivated by the recognition that accompanies contributions to the common stock of scientific knowledge (which explains why they publish results rather than be content with satisfying their task motivation by solving the problems). Stephan (1996) and Cohen and Walsh (2008) argued that this recognition may also be linked to the pecuniary motive that accompanies recognition for significant scientific accomplishments (including higher salaries, better working conditions, and monetary prizes such as the Nobel Prize).

Empirically, Walsh and Tseng (1998) found that the recognition motive, with its social context, elicits more active effort by workers, suggesting that non-pecuniary motives may be important for increasing productivity. Also, based on interviews of eight biotechnology firms, Judge, Fryxell and Dooley (1997) found that less innovative firms exclusively employed monetary rewards, whereas more innovative firms relied heavily on highly-personalized socio-emotional rewards like recognition. In their interview, a scientist working at a less innovative firm stated that they “can keep the money, what I want is the title” (p.78). In their study, all four of the most innovative firms surveyed implemented a personalized recognition system by tailoring non-monetary rewards to the unique needs of the recipients. Therefore, we would like to test following hypothesis:

> *Hypothesis C: Recognition motives are positively associated with commercialization of the invention.*

Humans have the basic need to search out safety, affiliation, and uncertainty reduction (Ashforth et al., 2008). As Weick (1995) described, uncertainties around the introduction of a new environment and changes in life could be mitigated when individuals associated themselves with a sense of belonging. By reducing uncertainties in their organizational affiliations, individuals are provided a sense of connection, a source of self-definition, and commitment to shared values (Ashforth et al., 2008).

We considered that the firm motive represents the individuals' need for security and affiliation. Within an organization, they can be satisfied with and feel secured by a sense of membership, which in turn reduces one's uncertainties. Therefore, the firm becomes a top priority in the lives of firm-motivated individuals. We expect that inventions created by them can be easily adopted and used within the context of the firm, because inventions will bear the inventors' understanding of the firm's need and capability. In particular, it is suspected that their inventions will have higher commercial value, as a firm's most important goal is generating profit.

Previous studies in organizational commitment suggested that commitment is positively related to individual and firm-level performance (Meyer & Allen, 1991; Mowday, Porter & Dublin, 1974). Meta-analyses have addressed how OC influences job performance (Mathieu & Zajac, 1990; Randall, 1990; Riketta, 2002; Wright & Bonett, 2002). Even though there are some mixed results, many studies reported that individuals with higher levels of organizational commitment perform better. Empirically, Hunter and Thatcher (2007) surveyed 410 bank employees, and showed that affective OC is positively associated with employee performance. Moreover, recent studies on OC have diversified the foci of the commitment, and introduced non-linear relationships to work outcomes. For example, Vandenberghe et al. (2006) found that organizational commitment had an indirect effect on job performance through commitment to the supervisor, and Morin et al.

(2012) have shown curvilinear association between commitment and outcome. Based on the interviews conducted, Judge et al. (1997) also suggested the importance of creating a sense of community in the workplace has in building an innovative atmosphere. According to these researchers, the most common phrase used by employees in the highly innovative firms was “family feeling;” a manager described that his team is very close and they frequently socialize together like a family. Judge et al. (1997) argued that this family feeling gives employees a sense of trust and caring.

Meyer and Allen (1991) suggested that better performance by employees with organizational commitment could be due to their desire to belong to the organization. They asserted that employees who want to maintain organizational membership are more likely to exert effort on behalf of the organization. Relating to the work effort, Sauermann and Cohen (2008) showed in their research that motives positively affect work effort. Even if their research did not include the firm motive, we expect a similar relationship with firm motive, effort, and resulting innovative performance. Following the previous literature, we suggest that firm motive is positively associated with innovative performance.

> *Hypothesis D: Firm motives are positively associated with commercialization of the invention.*

2.3.1 Motives and Scientists versus Engineers

The effect of motive on innovative performance can vary depending upon the nature of S&E professionals’ work, because industrial R&D covers a diverse set of activities and working conditions. Amabile's argument suggested that task motive and rewards are more closely associated with R&D tasks that require creative approaches and solutions for innovative activity. On the other hand, the pecuniary motive may govern innovative performance for those R&D tasks that require little creativity, but perhaps sustained effort (Amabile, 1993). Based on this, Sauermann and Cohen (2008) conjectured that pecuniary rewards might, for example, enhance performance in more downstream R&D tasks that are more routinized, such as clinical trials in pharmaceutical research.

Even though there is a large body of research on the effect of incentive and motive in different organizations (such as academia versus industry), there is very limited recent literature on the motive differences between R&D personnel within the industry. Research conducted in prior decades, however, studied this issue extensively in relation to cosmopolitan-local distinction (Allen, 1977; Kerr & Von Glinow, 1977; Miller, 1967; Pelz & Andrews, 1976; Ritti, 1968).

Research distinguishing scientists from engineers is based in the distinction between cosmopolitans and locals developed by Merton (1957), and extended by Gouldner (1957, 1958). The distinction between locals and cosmopolitans refers to, in Merton's terms, a basic orientation: one toward its immediate locale and the other toward the wider world.

One important difference between locals and cosmopolitans is their very different social-relational structure. Locals tend to be connected to, loyal to the local organization, and to maintain a strong orientation toward people in the local community (Gouldner, 1957a). On the other hand, cosmopolitans show a low need to be loyal to the organization;

displaying high commitment to their skills and expertise is of much more importance, as this group is oriented to an external reference group. In this regard, we can link motives and the local-cosmopolitan distinction. For example, we expect locals to be more group-oriented and committed to their organizations; while cosmopolitans, due to the fact that their identity lies outside their professional field, seek recognition more than any other motive.

Friedlander (1971) applied the local-cosmopolitan concept to the industry S&E workforce, and argued that where engineers are locals interested in management promotion, scientists are cosmopolitans focused on professional recognition. Shepard (1956) stated that cosmopolitans are productive and valuable to the company, but their outputs happen to be valuable to the company as byproducts of their work. These differences led both Merton and Gouldner to conclude that locals and cosmopolitans should be understood as distinct identities with very different implied roles.

Furthermore, Allen (1977) suggested the importance of educational training and socialization to the difference between scientists and engineers. They argued that industrial scientists are heavily influenced by their academic training, and thus are more likely to value specialized skills, focus on the scientific community, and desire autonomy and publication opportunities in order to develop a social reputation in the field. On the other hand, engineers in industry tend to seek more power positions and participation in organizations. Therefore, scientists and engineers have distinct responses to the goal of the organization. For example, engineers are more inclined to assimilate to the goal of the enterprise, unlike scientists, who are focused on attaining their own scientific goals. This suggests that industrial scientists are expected to be in conflict with corporate value systems, and to be disadvantaged in corporate incentive systems, which may lead to lower job satisfaction (Gouldner, 1957a; Kornhauser, 1962; Miller, 1967). This outcome is not desirable from the company's perspective either, as they have to pay the price of employing un-socialized PhDs (Allen & Katz, 1992, p. 242).

Based on the differences described above, we conjecture that the recognition motive is particularly correlated with higher innovative output for industrial scientists. The educational background and job requirements for research positions are particularly designed to push industry scientists to come up with cutting-edge inventions. As cosmopolitans, scientists are socialized to value specialized skills and recognition from the external scientific community. Accordingly, inventors with a high recognition motive and science backgrounds are expected to have stronger impact on commercialization than inventors with a high recognition motive and engineering backgrounds. We propose that inventors with a high firm motive and an engineering background would demonstrate higher performance than inventors with a high firm motive and science background. Since both an engineering background and the firm motive focus on local organization, these employees are loyal to the firm, and the goal of the organization is emphasized. Therefore, it is expected that inventors who are especially responsive to the firm would achieve more commercialization than inventors with a science background and/or other types of motives.

Hypothesis E: The improvement in innovation performance associated with recognition motives would be greater for inventors with science backgrounds than for those with engineering backgrounds (interaction effect).

Hypothesis F: The improvement in innovation performance associated with firm motives would be greater for inventors with engineering backgrounds than for those with science backgrounds (interaction effect).

2.4 Collaboration

Science improves upon what has already been studied (Cottrell, 1962). Even though science requires an individual's strong determination in pursuit of high excellence, it is the scientific community that generates, verifies and validates the idea that binds it. Communalism in science engenders collaboration, and takes place in the form of teamwork, cooperation and interdependence through communication and the exchange of research results (Allison, 1980; Cole & Cole, 1973; Fox & Faver, 1984; Merton, 1973a).

Since March and Simon (1958), many scholars have suggested that inter-organizational learning is important. Organizations can learn from collaboration as well as observing and adapting each others' practices (Powell, Koput & Smith-Doerr, 1996), which is critical to a firm's success. Understanding collaboration based on a network perspective and organizational learning, it has been suggested that a "network" of firms is critical in producing, recombining and transferring knowledge (Dyer & Nobeoka, 2000; Dyer & Singh, 1988; Powell, Koput & Smith-Doerr, 1996). As opposed to the traditional role of a firm in creating, storing, and applying knowledge (Kogut & Zander, 1992), it has been argued that the boundary of complementary assets extends outside of the single firm. Collaboration expands the network by serving in a brokerage role (Hargadon & Sutton, 1997), and a broader network is associated with the creative output (Fleming, Mingo & Chen, 2007). Therefore, collaboration in the network of firms can generate positive benefits that are otherwise unattainable (Dyer & Singh, 1988).

Furthermore, von Hippel (1988) emphasized the relationship between customer and supplier, and suggested that it is one of the primary sources of innovative ideas. He argued that the knowledge transfer mechanism among suppliers, users and manufacturers could be superior in innovation to less effective knowledge-sharing routines.

The open innovation perspective (Chesbrough, 2003) has also stressed external paths to innovation. Open innovation is contingent upon diverse sources of knowledge, including suppliers, customers, universities and competitors. Under the regime of open innovation, Chesbrough (2003) argued that companies strive to gain knowledge brokerage instead of knowledge creation. Empirically, based on a UK manufacturing firm survey, Laursen and Salter (2006) showed that there is an inverted U-shape relationship between innovative performance and the breadth of search through external sources of innovation. Also, Nagaoka and Walsh (2009) reported that external collaboration, particularly vertical collaboration, increases commercialization of the patent after controlling for the size of the project and the education of the inventor, both in Japan and the U.S.

Because firms are encouraged to procure knowledge externally, it becomes very important to evaluate external knowledge in order to succeed in innovation (Chesbrough, 2003; Cohen & Levinthal, 1990; Laursen & Salter, 2006; von Hippel, 1988). Taking advantage of external knowledge provides inventors with a large pool of recombinant technology components (Katila & Ahuja, 2002; Laursen & Salter, 2006; March 1991). Cohen et al. (Cohen, Nelson & Walsh, 2002) reported that start-up firms and large firms are more likely to take advantage of external knowledge from public organizations in their R&D projects. This is particularly true in the pharmaceutical industry, as shown by Zucker and her colleagues (Zucker, Darby & Amstrong, 2002; Zucker, Darby & Brewer, 1998). As to the relationship between external knowledge and innovation, Caloghirou, Kastelli and Tsakanikas (2004) suggested that external scientific knowledge increases the innovative performance of the firm in terms of sales attributable to the innovative product.

Collaborative activities in science and technology have significantly increased. For U.S. academic articles, the percentage of papers that had two or more authors increased from 55% in 1990 to 75% in 2010 (National Science Foundation, 2012). According to the NSF Science and Engineering Indicator 2012, collaboration bridges boundaries between fields, institutions, sectors and countries. For example, the percentage of papers that have international coauthors increased from 11.71% in 1990 to 31.57% in 2010 (National Science Foundation, 2012, Figure 5-25). Inter-industry collaboration, measured by coauthorship, has increased from 14.5% to 19.3% between 2000 and 2010 (National Science Foundation, 2012, Table 5-23). Furthermore, co-invention has increased internationally as indicated by the OECD Patent Database.[4] For patents granted in the U.S. Patent and Trademark Office (USPTO), the percentage with a foreign co-inventor has increased from 5.9% in 1999 (priority year) to 7.7% in 2008. Likewise, for the 27

[4] http://www.oecd.org/sti/inno/oecdpatentdatabases.htm

countries that comprise the European Union, the total cooperation with inventors abroad increased from 13.5% to 23.9% during the same period.

Hicks and Katz (1996) studied the growth of inter-institutional collaborations within the British system by investigating rates of co-authorship. In 1981, the average number of articles with co-authors was 2.63, which increased to 3.34 by 1991 with a linear increase of .08 ± .01. They argued that the increase in research collaborations was a general trend in science, facilitated by the competitive environment that requires pooled resources, skills, and competencies in order to make significant contributions. According to Jones (2009), collaboration has become the norm in scientific research because of what he called “the Burden of Knowledge:” the stock of scientific knowledge has increased and become so specialized that one cannot do everything, and scientists are forced to collaborate in order to employ broader knowledge stocks. Using U.S. patents between 1975 and 1999, he empirically showed that collaboration, measured by the number of inventors, has increased at a rate of 17% per decade (Jones, 2009).

Diverse aspects have been associated with the increase in collaboration. As science has become more specialized (Hagstrom, 1964), professionalized, and requiring of greater expertise, and disciplines have matured (Beaver & Rosen, 1979; Maanten, 1970), collaboration has increased. Funding structure also contributes to collaboration (Heffner, 1979). Particularly, government agencies have encouraged collaboration through requiring it as a condition for funding, especially between universities and industries (Walsh & Cohen, 2004). From the early 1980s, technology transfer policies have facilitated collaboration among researchers and industrial R&D organizations. For example, in 1980 the Stevenson-Wydler Act created the CRADA (Collaborative Research and Development Agreement). It permitted private corporations to select marketable products and processes from inventors of federal laboratories' intellectual property, and to work in collaboration with federal scientists to bring the product or process to market in order to facilitate joint research and development. Also, some technology programs such as the Advanced Technology Program (ATP) mandated inter-organizational collaboration as a prerequisite for government funding. As noted in the Conference Report that accompanied the bill, ATP was intended "to serve as a focal point for cooperation between the public and private sectors in the development of industrial technology." ATP provided seed funding to single companies or industry-led consortia of universities, businesses, and/or government laboratories for development of generic (broad-based), precompetitive technologies with applications across industries.

Technological and logistic advances have also caused easier and cheaper collaboration (Walsh & Bayma, 1996). Traveling has become less expensive. More significantly, communication methods have made physical distance less of a barrier between scientists so that collaborators can exchange news, data, reports, equipment, instruments and other resources much more easily (Finholt, 2002; Hesse et al., 1993; Kouzes, Myers & Wulf, 1996). In other words, the unavoidable transaction cost of collaboration has been lowered (Landry & Amara, 1998).

2.4.1 Motives and Collaboration

Fox and Faver (1984) noted factors that induce and prohibit collaboration, and Beaver and Rosen (1978) indicated 18 motives for collaboration. Empirically, Melin (2000) conducted research based on a survey of 195 university professors, and reported motive for collaboration. This indicated that many of the respondents collaborate because of "co-author's special competence," "co-author's data or equipment," "social reasons: old friends, past collaboration," and so on.

However, these studies focused more on the cost and benefits of collaboration rather than personal dispositions. This dissertation distinguishes from other researches in that regard. Instead of temporal motivation for collaboration based on advantages and disadvantages of collaboration, this dissertation investigates how motives – trait-like personal dispositions – affect collaborative activities. In fact, motives are suggested as one of the critical factors for transferring knowledge (Deci & Flaste, 1995; Lin 2007; Osterloh & Frey, 2000). For example, it has been argued that motives are critical in regard to the effort and time required to transfer knowledge and overcome concerns about ownership of information (Quigley et al., 2007).

For the inventor with a task motive, the most ideal form of incentive would be the task itself, because they are satisfied by what they are doing. Their locus of satisfaction resides in themselves so that, presumably, they would not like to share the joy of solving the certain research problem. Moreover, inventors with task motives prefer the autonomy and freedom to choose their own research topic, method, and execution. However, the nature of collaboration does not guarantee full-fledged freedom. Rather, it requires coordination, and it is difficult (Cummings & Kiesler, 2007). Because of the diversity of the group, coordination issues arise in the form of communication problems, conflict, and lack of cohesion and motivation (Ancona & Caldwell, 1992; Jehn, Northcraft & Neale, 1999; Miliken, Bartel & Kurtzberg, 2003; Reagans & Zuckerman, 2001). Dougherty (1992) claimed that different interdepartmental ways of thinking can lead to miscommunication, and is shown to result in poor performance (Ancona & Caldwell, 1992). Therefore, we can expect that inventors with task motives are less likely to collaborate than their other-motivated counterparts.

Additionally, collaboration is associated with transaction cost (Landry & Amara, 1998). Because of the nature of collaborative activity, it is necessary to discuss and negotiate ideas among collaborators. They need to plan the research, assign the work dependent upon an individual's expertise, and manage their progress in order to maintain coherence. Also, if one of the collaborators is not as committed to the work as much as the others, it can extend the length of time allotted, which can delay the project because collaborators need to wait for all parties to do their share of work before they can respond. Accordingly, it might take longer than the research executed alone. For some researchers, this is the cost that they don't want to pay, as narrated in Fox and Faver (1984): "…that takes time that I could probably go ahead and use to do it if working on my own" (p.352). Our data suggested that collaborative projects took longer to finish (even if we are not sure about the causal relationship). A lack in commitment by one or more collaborators may jeopardize the project by delaying its progress. Such slowdown has been the most common complaint about collaboration (Fox & Faver, 1984).

Given this possible time lag and uncoordinated routine, collaboration can sometimes be less productive than imagined. This is well documented in Perlow's study about Ditto's software engineers (1997). She portrayed how individual productivity is hampered, and so-called "time famine" is created by unsynchronized collaborative behavior. Furthermore, collaboration can be more expensive than working alone. Collaborators need to stay in touch and engage in social interaction among their working group, resulting in expenses incurred, e.g. phone calls, mailing fees, and travel costs (Fox & Faver, 1984). Even though collaborators can share expenses on data collection and management (Fox & Faver, 1984), and computer mediated communication has lowered the cost for communication (Walsh & Bayma, 1996), collaboration is not costless.

Another cost that can easily be neglected is the personal and emotional one. Fox and Faver (1984) indicated that collaborators pay the price for maintaining good relationships among group members. It is inevitable that individuals will have different opinions on collaborative projects, which can be time- and energy-consuming to alleviate. They need to find a good equilibrium between different perspectives and personalities. Without commitment, it is too costly to go through such negotiations; and collaborative projects can always be called off. In this regard, we can expect that inventors with task motives would not like to participate in collaboration, as they are focused on the puzzle itself. Unnecessary cost associated with collaboration is something they seek to avoid because it only hampers their problem-solving methodology.

However, collaboration can offer some degree of satisfaction in enhanced knowledge or self-competence through the act of providing knowledge to others (Kankanhalli, Tan & Wei, 2005; Wasko & Farag, 2005). Previous studies reported that employees with intrinsic motivation are more likely to participate in collaborative behaviors because it is associated with employee willingness to create a positive work environment (Deci & Flaste, 1995). Lin (2007) argued that a sense of competence or confidence could induce employees to involve themselves in collaboration. Moreover, through collaboration, an inventor can attain competencies and skills that had been lacking. The specialized technical capability of someone else may help with solving problems that a sole inventor would not have been able to achieve otherwise (Dyer & Singh, 1988).

Through sharing relevant knowledge, ideas, suggestions and expertise with one another, individuals add skills and competencies that help to solve problems (Hagstrom, 1967). Allen (1984) noted that one distinct feature of collaboration is "the exchange and circulation of ideas and practices among distributed networks of individuals located in diverse settings" (Powell & Giannella, 2010). In relation to social structure, Powell (1990) mentioned that collaboration gives timely access to quality resources and information. According to him, collaborative network structure is governed by the norm of reciprocity and reputational concern. Due to the reciprocity and "freer" environment that network entails, exchanged knowledge and information is considered to be better in quality than the information circulated under a hierarchical structure. In particular, Powell and his colleagues (Powell, Koput & Smith-Doerr, 1996) evidenced that, in the biotech industry, where knowledge matters in engendering competitive advantage, knowledge is created under the unstructured form instead of a tightly restricted organizational form. Because the network offers timely access to resources and information, it becomes the locus of innovation, not the individual firm, especially in a knowledge-based economy. They further argued that biotech firms are at a competitive disadvantage if they are not able to participate in "learning networks" (Powell, Koput & Smith-Doerr, 1996). Therefore, having and maintaining a collaborative network may be critical in order for engineers and scientists to be productive. Since it is not based on hierarchical structure, reciprocating and being respectful toward fellow collaborators is highly regarded as well. The sense of reciprocity, one of the founding mechanisms of this network structure, encourages employees to take part in collaboration, and thus enables long-term mutual cooperation (Bock, Zmud & Kim, 2005; Kankanhalli, Tan & Wei, 2005; Lin, 2007). Ongoing collaborations can develop trust, reduce uncertainty, and prevent shirking responsibilities, which can alleviate the high transaction costs associated with collaboration. Then, we can argue that employees who seek satisfaction from solving problems could positively affect collaboration.

Furthermore, collaboration saves time because certain expertise makes it easy to solve the problem (Fox & Faver, 1984), and helps reduce trials and errors. According to Fox and Faver (1984), one interviewee in their paper said that technological change was one of her motivations for collaboration. Technological innovation takes place so fast that researchers are required to obtain new information, and collaboration can aid that process. Also, Thorsteindottir (2000) indicated that collaboration permits use of expensive or unique equipment that is not otherwise available. Therefore, having access to certain equipment through collaboration has become necessary if researchers lack it. In other words, collaboration can not only increase efficiency (Heffner, 1979), but also the effectiveness (Presser, 1980) of the work. Aside from special expertise and explicit knowledge, it should be noted that tacit knowledge can be transferred through collaborative activities (Beaver & Rosen, 1978; 1979). Nonaka (1994) suggested that socialization, observation, and apprenticeship could be used to transfer tacit knowledge, and the relationship between advisor and graduate student is a good example of a situation where tacit knowledge is passed on (Bozeman & Corley, 2004); industry researchers are also expected to share their tacit knowledge when working together.

In summary, we suspect two possible effects of task motive on collaboration. First, task-oriented inventors are less likely to participate in collaboration because they are inclined to solve problems by themselves. Also, considering the cost associated with collaboration, task-motivated inventors would be less likely to participate in collaboration because it could decrease their focus on the problem. Second, task-oriented inventors could be more likely to participate in collaboration because it gives them competent and quality information to enhance their own problem-solving capabilities. In this dissertation, we propose that innate personal disposition toward solving problems would win over the decision on collaboration. Because inventors with a task motive seek autonomy and control over their behavior (Amabile et al., 1994), it is expected that they would not be willing to sacrifice their work preference, even if collaboration offers a wealth of information. Moreover, satisfaction from solving problems is where they are focused, so inventors with task motives may not enjoy receiving any sort of support. Therefore, we propose to test following hypothesis:

Hypothesis I: Task motives are negatively associated with collaborative activity.

Based on the positive effect of extrinsic rewards on worker participation (Fenwich & Olson, 1986) and goal expectancy theory (Vroom, 1964), it has been suggested that employees would be stimulated to collaborate when accompanied by extrinsic reward or incentive. Employees are expected to participate in collaborative behavior after weighing the cost and the benefit associated with collaboration. Here, the cost would include time and physical or mental effort associated with the behavior; the benefit would be possible organizational reward and creation of a sense of indebtedness for future collaboration (Lin, 2007). Based on incentive theory, Lawler (1981) suggested that a knowledge provider's decision to participate in the collaboration is found to be most predicted by a pecuniary motive. Osterloh and Frey (2000) also mentioned that an extrinsic reward such as money can effect the decision to participate in a collaborative team, even though its contribution cannot be guaranteed. Based on the argument of Amabile (1993),[5] Bartol and Srivastava (2002) theorized that extrinsic reward may hamper knowledge sharing to the extent that collaborators are not able to generate as many creative ideas. There is limited empirical research, but Lin (2007) found that expected organizational reward did not significantly increase employees' collaborative behavior.

As such, it is assumed in this dissertation that the pecuniary motive would not affect much of the collaborative activity. Moreover, collaboration is not cheap, both physically and emotionally. Sometimes, collaboration is so loosely structured that it can be stressful. The relationship between collaborators may be too informal to specify individuals' responsibility. Not knowing what they are responsible for could lead to a lack of commitment to the work (Fox & Faver, 1984). Moreover, Cummings and Kiesler (2007) noted the importance of coordination in predicting the success of a collaborative performance. If not managed properly, the diversity of the collaborative team can jeopardize the project by creating inefficiencies. Taking the coordination cost as well as possible under-performance into consideration, pecuniary-motivated inventors may hesitate to take part in collaboration. Even if the project is successfully finished, it has to go through a much more diverse screening process in order for it to be evaluated (Hessels & Lente, 2008). Furthermore, collaborators may need to share the reward once it is

[5] That extrinsic reward has positive effect on straightforward activities that require no creativity, while extrinsic reward is found to negatively influence activities that require creativity.

successfully commercialized. This would strongly dissuade monetary-oriented inventors from collaboration. After weighing the pros and cons of collaboration, inventors with the pecuniary motive may choose not to collaborate. Hence, it is expected that the pecuniary motive would not significantly affect collaborative activity.

Hypothesis II: Pecuniary motives have no significant effect on collaborative activity.

Working with well-known entities can improve exposure to the community. Stuart et al. (1999) called it "endorsement," and Podolny (2005) called it "status leakage," because collaboration with the renowned can endow legitimacy to the unknown individual and their work. Therefore, it is likely that the recognition-motivated inventor would seek these collaboration opportunities.

However, seniority may actually moderate the effect of the recognition motive on collaboration. For inventors with recognition motives, collaboration may not seem desirable for both the experienced and the inexperienced. In the phenomenon known as the Matthew Effect, the renowned scholar will get more fame, and the lesser known collaborator will get less (Merton, 1968;1973a). In the case of a junior researcher working with a famous researcher, both being listed as co-authors, it is possible that the less-renowned co-author will not receive the credit they deserve. No matter how the work was distributed, it is conceivable that the famous party has influenced the output more than the junior. Visibility is gained and the famous researcher lends credibility to the research, but credit is likely to be given disproportionately in favor of the recognized name. This is partly because of the difficulty in assessing contribution to the work, but also because of the cumulative advantage of the well-known entity. Moreover, considering the possibility that the famous name may be solely rewarded, a recognition-motivated inventor may not be inclined to work with that person.

On the other hand, from the senior's perspective, collaboration may not be beneficial because their productivity is already well known, and collaboration does not greatly increase their performance (Bozeman & Corley, 2004). Nonetheless, they already have an established network for collaboration, and are invited to collaborate in order to take advantage of their expertise, visibility or status (Stuart, Hoang & Hybels, 1999). Moreover, a collaborative network is known to help firms exploit market opportunities. Through collaboration, individual inventors can acknowledge the technological competency of each other, so that former collaborators can become consumers of the invention in the future (Stuart, Hoang & Hybels, 1999). Not to mention that the trust built among collaborators helps aid streamlined commercialization. Empirically, it has been shown that networks formed during the explorative stage are more likely to create networks for the commercialization stage of the innovation (Powell, Koput & Smith-Doerr, 1996; Rothaermel & Deeds, 2004). In other words, senior researchers who have a record of success through collaboration are expected to prefer other collaborations because they are aware of the increase their reputation will see in the firm due to successful commercialization. Moreover, network argument also claims that social relations can mitigate one of the obstacles suggested for collaborative activities: high transaction cost. Through repeated interactions, collaborators can develop trust, and are encouraged to share knowledge and information. Formal and informal knowledge shared in the network helps collaborators to reduce uncertainties, and the trust built in the network can prevent opportunistic behavior. Therefore, as inventors' seniority increases and their collaborative network ripens, collaboration grows less cumbersome. For inventors who have a higher recognition motive, a moderation effect is strongly expected, since broader and larger collaborative activities grant them a better reputation in their field. Therefore, we propose that seniority moderates the effect between the recognition motive and the propensity toward collaboration.

Hypothesis III: Recognition motives are positively associated with the instance of collaborative activity.

Hypothesis III-A: The relationship between recognition motives and collaborative activity is moderated by an inventor's tenure (interaction effect).

Inventors with firm motives are expected to be more likely to collaborate. Collaboration can generate a sense of helpfulness, and it has been suggested that it is positively related to knowledge sharing (Osterloh & Frey, 2000). Here, the sense of helpfulness resonates with prosocial motivation, so we suggest that a firm motive (equivalently referred in this dissertation as organizational commitment and prosocial motivation) increases collaborative activities.

Collaboration helps inventors remain connected to the community where they belong and alleviates a sense of isolation (Fox & Faver, 1984). Fox and Faver (1984) argued that some individuals can become detached from the scientific community, especially if the scientist is in a marginal group, such as women and scholars with heavy teaching loads in academia. Collaboration can ease this tension between their roles in research and other performances. Collaboration can also help them to keep in touch with research by providing opportunities to view current discourse on their research topics. Presser (1980) showed that collaboration and favorable review is highly associated with researchers in non-doctoral degree departments. This suggested that marginal members of the community are more likely to collaborate. In fact, our data shows a similar result. Even though female inventors comprise about 5% of our sample (100 out of 1854), they are more likely to have a greater number of co-inventors, co-invent within the firm, and co-invent with universities (significant at $\alpha < .05$ level). It also means that collaboration fosters a sense of belonging, camaraderie, and companionship in work. In their interviews (Fox & Faver, 1984), one female professor in a non-doctoral program noted that she didn't "want to buy expertise; I want to buy company" (p. 351). Therefore, we suspect that many work units are arranged at the team level because collaborative activities give people the chance to satisfy the need of companionship, as the above quote suggests. As such, we expect inventors with a firm motive who are inclined to feel secure within the group, would particularly favor intra-collaboration in order to gain a sense of camaraderie.

Kogut and Zander (1996) argued that a firm is different from a market because a firm coordinates, communicates and learns not only physically, in locality, but also mentally, in an identity. Sharing the same identity helps firms to lower the cost of communication, and to create explicit and tacit rules of coordination. Dyer and Nobeoka (2000) also claimed that individuals who shared the same identity with a larger collective created, combined, and transferred knowledge much more effectively. In fact, previous research argued that intrinsic motivation can be aligned with the firm’s strategic goals, shared purposes, and the fulfillment of norms for its own sake (Osterloh & Frey, 2000). Because of alignment with employees and the firm, intrinsic motivation serves as an organizational advantage through lowering transaction costs and raising trust (Nahapiet & Ghoshal, 1998). Quigley et al. (2007) described trust in relation to commitment, and claimed that trust was found to help collaboration (Szulanski, Cappetta & Jensen, 2004). With that said, we argue that collaboration should take place much more actively within the firm, because it is clear that employees from the same firm are more likely to share the same identity and goals as the firm. Szulanski and colleagues (1996; 2004) mentioned the ambiguity in recognition/reward-sharing and the amount of effort required for the knowledge-sharing to impede collaboration. However, inventors with firm motives would care less about who gets what from the collaboration. Rather, they would focus on the greater value to the firm, and it stands to reason that internal collaboration would not be hampered.

Moreover, collaboration within the firm can help protect confidentiality. Since inventors' behavior signals their pledge to the organization, they would not want to share the property rights with collaborators working outside of their firm. It would not be beneficial to the firm in that regard, so the inventor with a firm motive would be less likely to co-invent with an external entity.

Hypothesis IV: Firm motives are positively associated with collaborative activity.

Hypothesis IV-A: For inventors with firm motives, the difference in collaborative activity is larger for internal collaboration than for external collaboration (interaction effect).

CHAPTER 3. DATA AND MEASURES

To investigate our research questions, we have collected the novel data consisting of multiple data sources, including a U.S. inventor survey and archival datasets such as USPTO CASSIS. The major data is the “The Georgia Tech/RIETI 2007 Inventor Survey: Inventors and Their Inventions” (The GT/RIETI Survey, 2007). Patent documents are used a number of times to examine recombination of technology components (Fleming, 2001; Gruber, Harhoff & Hoisl, 2012). The next section describes the GT/RIETI Survey and additional archival data regarding its sampling design, survey instruments, and the variables used for this study.

3.1 Data

3.1.1 The GT/RIETI 2007 Inventor Survey

This project used a unique dataset based on a nationally representative survey of inventors in the U.S. “The Georgia Tech/RIETI 2007 Inventor Survey: Inventors and Their Invention” was conducted in the summer of 2007. The population was the 32,390 U.S. patents that had been applied for at the European Patent Office (EPO) and Japanese Patent Office (JPO), and that were granted by the U.S. Patent Office (USPTO), with priority years from 2000 to 2003 (inclusive), and having at least one inventor with a U.S. address. Those patents were included in the Organization for Economic Co-operation and Development (OECD) triadic patent family. These "triadic" patent families represent patents that the patent owners feel have significant value (enough to take on the expense of filing a patent in three jurisdictions) and a potential global market.

However, we should note that not all inventions are patented, and that patent propensities vary by industry, so we should be careful when making inferences from this population (Cohen, Nelson & Walsh, 2000b). Specifically, this population is not a random sample of the S&E workforce, but rather represented that subset of inventors who had successfully created a patented invention (and likely, a fairly valuable invention). Still, this population represents a significant subset of inventors, and yielded U.S. inventors with global patents and therefore can be thought to consist of especially important patents with higher chances of commercialization. Thus, if inventors with specific motives were especially active in this population of inventors, this is stronger evidence that they have made a significant contribution to the U.S. innovation system than we would get from a random sample of all U.S. patents, which would include many trivial and low-value patents (cf. Harhoff, 1999; Gambardella et al., 2008) (Gambardella, Harhoff & Verspagen, 2008; Harhoff et al., 1999).

Note that this sampling strategy did not distinguish between those in an R&D function, those having an S&E degree, or even invention as a primary work activity. Instead, this sample consisted of those who had actually invented. Also, by surveying inventors about specific patents, we were able to link inventor characteristics (such as education and experience) with invention characteristics (such as the value or commercialization of that specific patent), project characteristics (inventor-months dedicated to the project) and firm characteristics (such as size), which gave us a more detailed picture of the contribution of inventors' motives (net of other predictors of valuable inventions). We also directly linked our survey data to bibliometric indicators (such as novelty, forward citations and number of inventors), so that our study could combine the strengths of prior survey-based studies with those of bibliometric-based studies.

We drew a systematic sample of 9,060 triadic patents with at least one U.S.-addressed inventor, stratified by the National Business Economic Research (NBER) technology class (Hall, Jaffe, & Trajtenberg, 2001). Taking the first available U.S. inventor as the representative inventor, we collected U.S. addresses from the EPO database or other sources as needed (e.g. phone directories). If we were not able to find any valid address for that inventor, we took the next U.S. inventor of the patent and searched their U.S. address accordingly. Then, we randomly drew one patent for inventors with multiple patents in our sample. Finally, we had 7,933 unique US-based inventors in our mail-out sample. In our analyses, we used sampling weights (inverse probability of selection) to adjust for multiple-patent inventors.

The survey was operated in mixed-modes: web and mail surveys. In the survey packet, we included individualized, signed cover letters (including information on the web-based survey URL), questionnaires, and first-class stamps. Respondents could choose to respond either by post or online. After sending the survey packet, follow-up letters, and a second-wave mailing of the full packet (Dillman, 1978), we received 1,919 responses (24.2%). After excluding undeliverables, deceased, etc., from the denominator, we had an adjusted response rate of 31.8%. Item non-response reduces the totals somewhat for specific items.

Using data from the patent documents for the full set of respondents and non-respondents (N=7,933), we also conducted non-response bias analyses. We found little evidence of non-response biases that were either statistically or substantively significant. In particular, measures of collaboration (solo inventions: 27% for respondents, 26% for non-respondents; average number of inventors: 2.71 for respondents, 2.80 for non-respondents), links to universities (citations to non-patent literature: 2.4 for respondents, 2.7 for non-respondents), and measures of patent value (forward citations, 2.2 for respondents, 2.4 for non-respondents) were all similar ($p<. 05$, N=7933). The only significant differences were that inventors for which we only had a company address (instead of home address) were less likely to respond (4% of respondents had a company address versus 6% for non-respondents, $p< .001$) and those with more patents were more likely to respond (mean of 1.18 patents for respondents, 1.13 for non-respondents, $p< .001$), although the absolute differences are quite small. Thus, despite the modest response rate, we have some confidence that our sample is representative of the underlying population of US-based inventors on triadic patents.

The GT/RIETI Survey focused across the innovative landscape, not limiting our analysis to high-tech sectors or to particular industries (such as biotech or IT). Our data allowed us to combine the inventor, project and company-level information from the survey with invention-level information on a particular, named patent to examine the value and outcomes of each invention. Therefore, unlike prior work, we were able to estimate patent-level models of invention performance, controlling for detailed field, firm, inventor and project-level characteristics. We have multiple measures of patent quality, including: self-reports on whether the patent ranks in the top 10% in terms of technical significance in its field, self-rated top 10% in economic value, and the number of forward citations, as well as patent novelty (described below). Our data also has information on the highest educational degree attained.

3.1.2 Technology Subclasses Based on the Patent Archive

In this dissertation, we used patent data from Lai et al. (2011) in order to form the creativity measure used in Chapter 4. Merging multiple data such as the U.S. Patent Office (USPTO) and the NBER, Lai et al. have collected diverse variables including our focal interest: the U.S. Patent Classification (USPC). According to Lai et al.(2011), they collected USPC from USPTO CASSIS, which reflects November 2009 concordance. USPTO organized all technology into approximately 100,000 categories. The dataset has information on U.S. utility patents granted from 1975 to the present. Instead of International Patent Class (IPC), we have used USPC as the proxy of creativity for the following reasons: Not only is there a well-established tradition utilizing USPC for measuring recombination (e.g. (Fleming 2001; Fleming, Mingo & Chen, 2007), but also the USPC is periodically updated and overwritten for past patents, a process by which data integrity between current patents and previous patents is maintained. Moreover, the updated class reflects current, rather than past, views on the cognitive blocks of technology. Following Fleming et al. (2001; 2007), we measured recombination using technology classification.

3.2 Measures

In this section, we describe variables used for analysis to test the aforementioned research questions. We begin by introducing dependent variables, including innovative performance, new recombinations and collaboration. Next, we explicate independent variables, i.e., individual motives and education background. Control variables are also described. The list of variables and the data source is presented in Table 3.3.

3.2.1 Dependent Variables

New Combinations

To examine if the subclass pairing in the GT/RIETI Survey is original, we began by constructing a pair of technology subclasses for every U.S. utility patent granted from 1975 and filed by 1999, based on Lai et al. (2011). Since the GT/RIETI Survey included patents filed from 2000 to 2003 (inclusive), we used the cut point of patents filed by 1999. The database included 2,534,035 patents, and 435,133 unique pairs of technology subclasses. We took the GT/RIETI Inventor Survey 2007 as one cohort, and also created a pair of USPC technology subclasses for every sample in the survey. Then, we compared the GT/RIETI Survey subclass pairs to the base data, and constructed a dummy variable coded 1 if the subclass pair had never been introduced in the base data; otherwise 0.

The results showed that the GT/RIETI Inventor Survey had 10,434 unique subclass pairs, and 1,004 patents with at least one new subclass pair. Again, the GT/RIETI Inventor Survey 2007 included a total sample of 1,919 patents. It may seem little bit high that 52.32% of the sample has at least one new subclass pair. However, we need to take into account that our sample is based on the triadic patent family. Applying for a patent in the US, Japan and EU shows its significance in terms of technical value as well as commercial appropriability. Likewise, triadic patents can be more creative. In fact, the robust check on the creativity measure with a random sample of 100 U.S. patents from the USPTO showed that 37% of them had at least one new combination. This result provided us some confidence in our measure, contrasted with the fact that 52% of triadic patents in the GT/REITI survey had at least one new technology subclass combination. Moreover, we must take into account the fact that there are many possibilities having at least one new combination. There are more than 100,000 USPC subclasses (Fleming, Mingo & Chen, 2007; Harris, Arens & Srinivasan, 2010), so we can assume that 5,000,000,000 possible subclass pairs can be generated (100,000* 100,000/2). When we processed existing technology subclass pairs from utility patents granted from 1975 and filed by 1999, we came up with 10,789,819 technology subclasses. After creating pairs and cleaning duplicates, we found about 435,000 existing technology pairs for the given period. In other words, little less than 5 billion technology subclass pairs have still not been observed. Therefore, we are confident that our 52% of the triadic patent sample has at least one new combination.

Moreover, Jung and Lee (2012) created a measure that indicated new recombinations of subclasses in the nanotechnology class. In their research, the sample included all nanotechnology patents granted from 1980 to 2008. Their creativity measure indicated that 28% of nanotechnology patents included new subclass pairs within the nanotechnology class (USPC Class 977), and 81% of nanotechnology patents included a new subclass pair across all technology subclasses.

Since our dataset also encompassed all technology subclasses, we can validate that our creativity measure shows a reasonable rate of novelty. On top of that, we ran correlation analysis between new combinations and other variables in order to validate our measure. The result indicated that new combinations and technical significance are weakly ($p < .10$) but positively correlated (r = .058). Focusing on new combinations that only include primary subclasses, we found a stronger correlation (r = .090 at $p < .05$). Also, variables indicating strength of the patent, such as number of claims and number of cited U.S. patents, were correlated against new combinations (Gambardella, Giuri & Luzzi, 2007; Lanjouw & Schankerman, 2004). The result indicated that the number of claims was positively correlated with new combinations (r =.114), illustrating that new combinations have broader appropriability.

Table 3.1 Correlation for New Combinations

	Variables	Mean	S. D.	1	2	3	4	5	6	7	8
1	New Combinations	0.54	0.50								
2	New Combiantions_Primary class	0.31	0.46	0.612 ***							
3	Technical Significance	0.16	0.37	0.058 *	0.090 ***						
4	Number of different USPC Subclass	4.54	3.38	0.474 ***	0.332 ***	0.110 ***					
5	Number of other cited reference	2.47	8.49	-0.018	-0.008	0.103 ***	0.077 **				
6	Number of claims	23.31	16.76	0.114 ***	0.066 **	0.065 **	0.062 **	0.067 **			
7	Size of the project	21.07	24.21	0.009	0.005	0.206 ***	0.034	0.041	0.008		
8	Enhancing Technology Seeds	0.23	0.42	0.002	-0.026	0.035	0.006	-0.001	-0.026	-0.035	
9	Creating Newline of Business	0.26	0.44	-0.038	-0.059 **	0.067 **	-0.037	0.031	0.055 *	0.119 ***	-0.323 ***

* p <.10, **p<.05, ***p<.01

Commercialization

The GT/RIETI Survey had a unique measure for innovative performance, which had not been reported often. Our survey asked respondents if their patented invention was commercially used. Questions included information regarding the commercialization of an invention in a product/process/service by the applicant/owner; licensing by (one of) the patent-holder(s) to an independent party (including cross-licensing); and whether the invention was used to establish a new start-up company. These categories are not mutually exclusive (e.g., the same patented invention can both be used in-house and be licensed). Based on these categories, we constructed an aggregated commercialization variable by coding it 1 if the patented invention fell into any of these three categories, and 0 otherwise. This was used as a proxy for innovative performance in this dissertation. Previous research has used salary (Stern, 2004) and number of patents generated (Sauermann & Cohen, 2010) as indicators of inventor performance. Unlike those measures, our measure directly tested whether the invention was put on the market. Therefore, it is expected that commercialization tells more about innovative performance, closer to what has been mentioned by Schumpeter (1942). A detailed analysis on commercialization of the patents, examining modes of commercialization and their correlates, is beyond the scope of this dissertation, but see a recent study by Jung for more information (2009).

Collaboration

Previous work has measured collaboration by using co-inventorship, co-assignee, citations, licensing, joint ventures, and other methods (Arora, Fosfuri & Gambardella, 2001; Branstetter & Sakakibara, 1998; Hagedoorn, 2003; Hicks & Narin, 2001; Jaffe, Trajtenberg & Henderson, 1993; Sakakibara, 2002). Whereas these formal measures captured the relationship between collaboration and innovation, they were limited in the sense that codified information only reflects part of the underlying activities (Walsh & Nagaoka, 2009). For the sake of simple property rights, for example, some patents are only assigned to a single assignee, even if it is the result of a multiple firm collaboration (Hagedoorn, 2003).

Having said that, in order to understand the cooperative behavior thoroughly, the GT/RIETI Survey measured collaboration in various ways. In addition to the information that was publicly available (i.e. co-assignee, citation to a prior patent or publication), the GT/RIETI Survey included a unique approach to measure inventors' collaboration patterns. First, it questioned how many co-inventors were listed in the focal patent, and what types of organization the co-inventor worked for. The types of firm included same firm, suppliers (including contractors), customers and users, competitors, non-competitors within the same industry, other firms, universities, government research organizations, hospitals, and private research organizations. In this way, we were able to determine the number of co-inventors as well as their physical locality (either internal or external).

In order to examine the collaborative pattern in more detail, we recoded survey measures into internal and external collaboration. The same firm categories were considered as internal co-invention and collaboration, and other categories were coded into external co-invention and collaboration. We first made it as a dichotomous variable, “Any Co-invention,” coded to 1 if there were any external co-inventors; otherwise, it was 0. Then, we counted the number of external co-inventors and created a count variable, “Number of external co-inventors.”

3.2.2 Independent Variables

Motives

We asked respondents to rate the importance of eleven factors when researching the focal patent[6]. Respondents rated the importance based on a 5-point scale from 1, not important, to 5, very important. Following is the list of each factor: 1) Satisfaction from solving technical problem, 2) Satisfaction from contributing to the progress of science and technology, 3) Job to invent, 4) Generating the value for the firm, 5) Career advances and opportunities for a new/better job, 6) Prestige/Reputation, 7) Recognition from co-workers, 8) Recognition from others in the same profession (outside the firm), 9) Beneficial working conditions from my company (e.g., increased research budget), 10) Monetary rewards, and 11) For societal good.

Even though we have only used samples from industry in our analysis, we compared the mean score of the motives between those in firms and those in public research organizations in order to validate our measure. As reported in Figure 3.1, inventors from public research organizations were significantly more motivated by seeking satisfaction from contributing to the field, but indicated a lower range of motivating factors in generating value for the firm. This result gives some confidence to our motive measures

---

[6] The question was phrased as follows: During the research leading to the focal patent, how important to you were the following reasons to work on inventing?

based on previous research about the academic S&E workforce (Sauermann & Cohen, 2010).

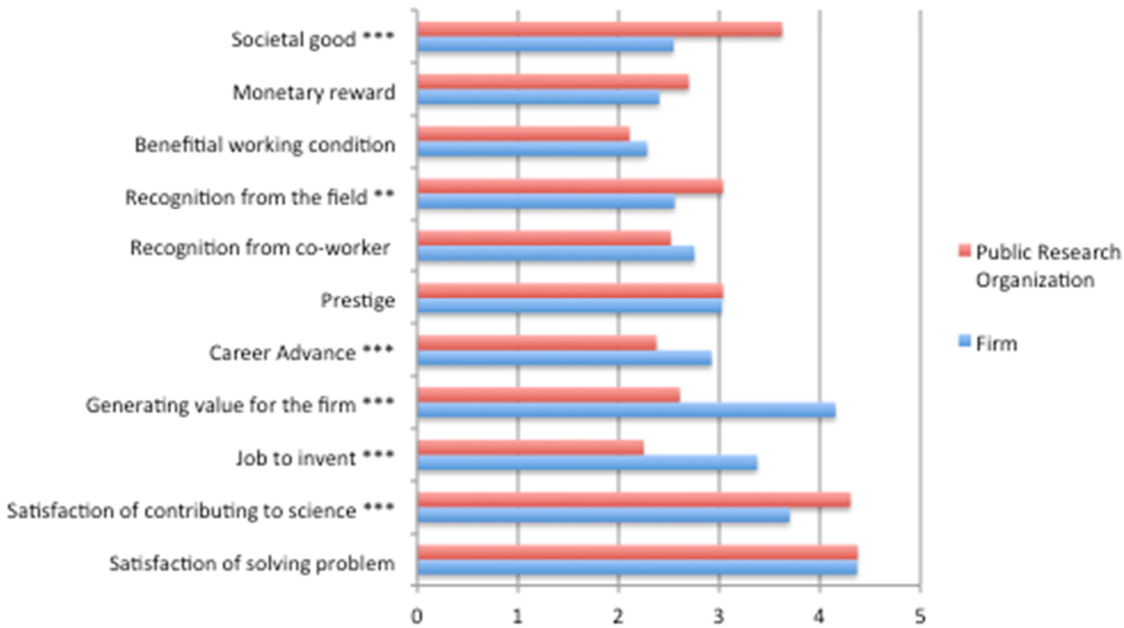


Figure 3.1 Mean Score of Motive, Firms versus Public Research Organizations

Based on theoretical framework suggested by Ryan and Deci (2000), we initially conducted a factor analysis with two dichotomized motives: intrinsic and extrinsic motives. However, as reported in Table 3.2, we were not able to find that factor loadings aggregate based on the theory. Therefore, we employed a factor analysis with four motives: task, pecuniary, recognition, and firm motives. Results indicated that recognition motive was picked up by four categories: 5) Career advances and opportunities for a new/better job, 6) Prestige/Reputation, 7) Recognition from co-workers, and 8) Recognition from others in the same profession (outside the firm).

Table 3.2 Factor Analysis on Motives

	Factor 1	Factor 2	Uniqueness	Factor 1	Factor 2	Factor 3	Factor 4	Uniqueness
Satisfaction of solving problem	0.3398	-0.1382	0.8654	0.1837	0.5056	0.045	-0.0296	0.7077
Contributing to science	0.4724	-0.1072	0.7653	0.2869	0.5494	0.0398	0.0948	0.6052
Job to invent	0.2017	0.4433	0.7628	0.1621	0.0976	0.4968	0.1079	0.7057
Generating value for the firm	0.0546	0.4257	0.8158	0.0537	0.0021	0.4777	0.0298	0.768
Career Advance	0.5978	0.3692	0.5063	0.6148	-0.0072	0.2974	0.1956	0.4952
Prestige	0.791	0.0718	0.3691	0.8099	0.1177	0.0577	0.0286	0.326
Recognition from co-worker	0.7758	0.1075	0.3866	0.8034	0.0706	0.0641	0.0682	0.3408
Recognition from the field	0.7652	0.011	0.4144	0.7231	0.1965	-0.034	0.1751	0.4067
Benefitial working condition	0.472	0.2819	0.6977	0.3825	0.1123	0.1582	0.4506	0.613
Monetary reward	0.3187	0.204	0.8568	0.2691	-0.0039	0.0487	0.4029	0.7629

Moreover, an internal consistency test showed a Cronbach alpha score of .85, above the recommended threshold value of .70 (Nunally, 1978); therefore, the factor score was used for the propensity toward the recognition motive in the analysis. For other motives, the eigenvalue did not exceed 1; hence, we first employed a factor-based score method. Grounded on theoretical framework and the result of exploratory factor analysis, the task motive included: 1) satisfaction from solving technical problem, and 2) satisfaction from contributing to the progress of science and technology; the monetary motive included: 9) beneficial working conditions from my company (e.g., increased research budget), and 10) monetary rewards; and the firm motive included: 3) job to invent, and 4) generating the value for the firm. However, internal consistency turned out to be lower than the conventional level (reliability coefficient of .70 or higher); .52, .57, and .50, respectively for monetary, task, and firm motives. Therefore, we decided to employ a single indicator for each concept in order to fully describe which measure explains the most of the dependent variable, though we may introduce some measurement error. Accordingly, we chose 1) satisfaction from solving technical problem, 4) generating the value for the firm, and 10) monetary rewards for task, firm and pecuniary motives, since they are stated much closer to the motives described in this study.

Educational background

We questioned the respondents' educational backgrounds by asking in which discipline their highest degree was earned (such as Mechanical Engineering and Biochemistry). The response was provided in an open-ended format, and we recoded and aggregated them based on NSF Discipline Codes. Removing Social Science and Humanities majors (Sociology, Economics, History, Anthropology, Social Psychology, Psychology, Linguistics, Political Science, and other Social Sciences), we constructed a dummy variable indicating Science background, which included Physics/Astronomy, Mathematics, Chemistry, and Life Sciences (i.e. Biological Science, Environmental Biology, Agricultural Sciences, and Medical Sciences). Engineering background was comprised of Computer Science, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Matallurgy and Material Engineering, Aeronautical Engineering, and Other Engineering fields.

Tenure of the Inventor at the Organization

Tenure was included in the analysis because not only does it measure job specific skills and knowledge, but can also capture the cohort effect (Sauermann & Stephan, 2010; Stephan, 2010; Stephan & Levin, 1996). In the GT/RIETI Survey, we asked respondents to indicate “the year in which this [highest] degree was earned.” We recoded the responses into a continuous variable by subtracting them from the patent filed year. In other words, the tenure variable indicated years of inventor experience after graduation, until the year that this focal patent was filed.[7]

Inventing Hours

We created a variable for measuring inventing hours, since motives affect effort put into the work, and effort is shown to exert a positive effect on higher productivity (Sauermann & Cohen, 2010). We asked about work hours in a week and the share of overall working time devoted to “inventing” or R&D activities at the time of invention. The question wordings were: “At the time of the invention, about how many hours did you work in a typical week?” and “Please tell us the share of overall working time you spent on ‘inventing’ or on R&D activities at the time of the invention.” After coding as missing those that answered working more than 150 hours a week (N=2), we created an “inventing hours” variable by multiplying the hours worked in a week and the share of the work time spent on inventing. Here, we specifically picked inventing hours instead of work hours, because the former would reflect exact time devoted to invention.

[7] We also have measures of individuals' age, tenure in the current job, and tenure in the technical field of the patent. Since those variables are highly correlated with the tenure variable, we only include *tenure* in regressions. Robustness checks show very similar results.

Inventor Education

Prior literature reported that inventors with higher education levels had a more abstract understanding of problem solving (Gruber, Harhoff & Hoisl, 2012). Also, given the unlimited possibilities of recombination, inventors are bound to choose a technological component near their knowledge and experience (Fleming, 2001). Level of education attainment is also known to be associated with cognitive ability (Pelled, 1996). Moreover, according to Hargadon (2006), higher levels of education raise the possibility of boundary-spanning activities. Therefore, higher education, which reflects in-depth knowledge and experience as well as higher cognitive ability, is particularly expected to increase the propensity of technology recombination.

We asked, “When the research leading to this patent was conducted, your highest degree was...” Six categories for answer ranged from “High school or lower” to “PhD, MD or equivalent.” We then created dummy variables standing for bachelor’s, master’s, and PhD degrees. Advanced degrees such as master’s and PhDs were included in the model, and bachelor’s degrees became the exclude category.

3.2.3 Controls

Technical Significance

We asked respondents to rate their patent’s technical significance in the U.S. to examine the value of the patent. Respondents ranked the patent (compared to other inventions in the U.S. in their field during that year) as in the top 10%, between top 10% and top 25%, between top 25% and top 50%, and the bottom half. According to previous studies conducted in Europe and Japan, self-reported patent values were found to be closely matched with expected correlates of value, such as inventor-months devoted to the project, commercialization of the invention, citations to the patent, and inventor self-assessment of the monetary value of the patent (Giuri, Mariani et al., 2007; Nagaoka & Walsh, 2009).

Size of the project

We built a control for the inventor months used in the project that produced the patented invention based on a question in the survey. It was an ordinal variable created from the question, "Approximately how many man-months did the research leading to the focal patent require?" From nine answer categories, ranging from "less than one man-month" to "more than 97 man-months," we took the median value and recoded it accordingly.

Types of R&D

Using the survey, we were able to discern if the patent was invented for creating new lines of business, enhancing existing lines of business or expanding the technology base of the firm/long term cultivation of the technology seeds. Patents resulting from projects designed to strengthen the company's technological base might have lower commercialization. Accordingly, we created the dummy variable "new line" and "enhancing technology base." We coded 1 for "new line" when the respondent indicated the inventions' objective was to create a new line of business; and likewise, we coded 1 if the respondent answered that the invention was created for the purpose of cultivating technology seeds for the firm. Having those two dummy variables in the model, the exclude category became “enhancing existing line of business.”

Number of Inventors

The number of inventors on a patent application is one of the measures for examining the resources put into in producing focal invention. The number of inventors was collected from the patent documents registered at the U.S. Patent Office.

Size of the organization

The size of the organization is likely to affect dependent variables, particularly commercializing behavior. For example, Gambardella et al. (2007) asserted that the size of the firm is an important indicator for a company’s propensity in licensing. Cohen and Klepper (1996) summarized consistent findings of early studies that R&D investment increases as a firm size increases, but the innovation output (mostly examined by using patent counts) decreases disproportionately as firm size increases. Furthermore, it would impact collaboration pattern. Since small firms may be more protective of their intellectual property, they may be less likely to externally co-invent. On the other hand, because they have fewer resources, they may have greater need to collaborate. Also, firm size is likely to affect the value of the patent (since small firms may be more constrained in their propensity to patent, focusing only on the most valuable) and the commercialization rate, due to the presence or absence of complementary assets or the likelihood of engaging in strategic patents (such as blocking patents or defensive patents, which may be of low value and unlikely to be commercialized) (Cohen, Nelson & Walsh, 2000a).

Thus, we included a control for organization size, using three dummy variables: 1) Large firm, coded 1 if the inventor belonged to a large firm (defined as having more than 500 employees) at the time of invention and 0 otherwise; 2) Small firm, coded 1 if the respondents belonged to a firm with less than 100 employees, and 0 otherwise. Belonging to a medium-sized firm (100-500 employees) was the excluded category.

Strength of Patents

In this dissertation, we employed two variables to measure the strength of patents: the number of different technology classes and the number of claims. The number of technology classes has been used in previous studies (Gambardella, Giuri & Luzzi, 2007; Jung, 2009) to measure the strength of patents. Also, it is considered a measure of complexity of technology (Nerkar & Shane, 2007).

Number of claims is also a measure of patent scope (and hence value) (Lerner, 1994). Since each claim is considered an independent patent (Tong & Frame, 1994), the number of claims is sometimes used as a proxy for breath of utility or applicability of the patent. Lanjouw and Schankerman (2004) used this variable as a control for patent strength.

Technology dummies

We employed controls for technology sectors (using dummy variable controls, five 1-digit NBER categories with "Miscellaneous" as the excluded category) based on the assumption that there may be a difference in the general trend by specific technology sectors. For example, there are likely to be higher rates of commercialization in particular technologies.

Additional controls

We used patent-filed year fixed effects. Our patent filing years span 2000 to 2003. Additionally, we used sampling weights, calculated as the inverse probability of selection of that patent divided by the mean probability of selection, so that inventors with multiple patents (hence a lower probability of having a given patent selected for the survey) get greater weight in our analysis. This weighting produced unbiased estimates of the population means.

Table 3.3 List of Variables and Brief Description

Variable		Description	Data Source
Dependent Variables			
Commercialization		Dummy variable coded 1 if the patent is commercialized	GT/RIETI Survey
New Combination		Dummy variable coded 1 if at least one pair of technology subclasses is never introduced between 1975-1999	USPTO, Lai et al.
Collaboration	Any Internal Co-inventor	Dummy variable coded 1 if there is any outside co-inventor formally listed in the patent document	GT/RIETI Survey
	Number of Outside Co-inventors	Number of outside co-inventor, formally listed in the patent document	GT/RIETI Survey
	Any Internal Co-inventors	Dummy variable coded 1 if there is any internal co-inventor formally listed in the patent document	GT/RIETI Survey
	Number of Internal Co-inventors	Number of internal co-inventor, formally listed in the patent document	GT/RIETI Survey
Independent Variables			
Motive	Motive	Ordinal/Continuous variable indicating the degree of inventor motivation	GT/RIETI Survey
	High motive	Dummy variable coded 1 if a inventor responded such motive is important and very important	GT/RIETI Survey
Educational Background		Major discipline of the inventor: science or engineering	GT/RIETI Survey
Tenure of the Inventor		Continuous variable indicating inventor experience from graduation to the patent filed year	GT/RIETI Survey
Inventing Hours		Hours worked in a week * percent of work devoted to inventing	GT/RIETI Survey
Controls			
Technical Significance		Dummy variable coded 1 if the patent ranked as the top 10% (self-reported)	GT/RIETI Survey
Inventor Education		Highest degree earned	GT/RIETI Survey
Size of the Project		Inventor-months for the project leading to the patented invention	GT/RIETI Survey
Types of R&D		Dummy variables indicating the project is aimed to 1) create new line of business, and 2) cultivate technology seed. Excluded category is for enhancing existing business	GT/RIETI Survey
Number of Inventors		Number of inventors on the U.S. patent	PATSTAT
Size of the Organization		Dummy variables indicating the size of the firm: large firm means more than 500 employees, small firm means less than 100 employees. Excluded category is the medium sized firm	GT/RIETI Survey
Technology Dummies		Dummies of six technology fields are included: Chemical, Computer & Communication, Drug & Medical, Electrical & Electronic, Mechanical, and Others. Excluded category is the “others”	PATSTAT
Patent Filing Year		The year that the patent was filed	PATSTAT

3.3 Descriptive Statistics

Out of the total 1,919 patents in the GT/RIETI Survey, this dissertation is only focused on industry R&D inventors with science and engineering backgrounds, decreasing the sample size to 1,232 cases. We further removed cases that had missing values for motives, reducing our sample to 1,175. This is the base number for our descriptive statistics. Moreover, we used sampling weight to better estimate the expected value of the measures for descriptive statistics. For the analysis of each chapter, we removed cases that had missing values in dependent variables, so that each chapter has different total cases.

To begin, we have summarized descriptive statistics in Table 3.4. About 61% of patents in the sample were commercialized, including the forms of licensing and startup companies. Again, we identified a patented inventions commercialized if it was (a) commercialized in a product/process/service by the patent applicant or owner of the patent; (b) licensed out or cross-licensed by one of the patent holders to an independent party; or (c) commercially exploited by the respondent or any co-inventors for starting a new company. At first glance, it seems that 61% of the sample being commercialized is high. However, taking into account that our sample was made up of triadic patents, applied for both in Europe and Japan, and then granted in the U.S., this sample has high potential for commercialization.

As to the new combinations, about 53.6% of the patents in the sample had at least one new USPC subclass combination. Again, after comparing that with the result of Jung and Lee (2012) and the result from the random sample drawn from the USPTO, it seemed reasonable that we might get a number this high from the triadic patent sample. In terms of the collaboration measures, we took advantage of the GT/RIETI Survey in order to investigate collaborative behavior in various ways. Registered number of inventors for the focal patent in USPTO was 2.8 on average, and solo inventors generated approximately 25% of the sample. Approximately 11% of the sample had at least one co-inventor from outside of the firm, and 71% of the sample had at least one co-inventor from the same firm. Detailed descriptions of the new combinations and collaboration measures are presented in the following sections.

Looking at the individual-level statistics, we found that a significant number of inventors—50%—hold a PhD, and another 25% had a master's degree as their highest degree earned. As for educational backgrounds, about 43% of the inventors were science majors, and 57% of the sample had an engineering degree (with social science and humanities excluded). Female inventors only accounted for less than 5% of the sample, and the mean age of the sample was 46 years. On average, inventors worked 26.3 hours a week on inventing, which was calculated by multiplying the hours worked in a week and the share of the work time spent on inventing. Also, inventors had approximately 18 years of experience after graduating with their highest degree, before filing the focal patent application. In terms of firm size, most of the inventors belonged to large firms with more than 500 employees (about 82%), but small-firm (with employees fewer than 100) inventors comprised about 11% of the sample.

Project-wise, an average of 21 man-months were spent in creating the focal patent. About 23% of the project was aimed at cultivating technological seeds, and 26% of the project resulted from the endeavor to create a new line of business in the organization. The distribution across technology classes was fairly even; nonetheless, the chemical sector stood out, accounting for 24% of the sample.

Even though we did not include the following measures in the model, we disclose these here for better understanding; after taking out outliers for a number of disclosures and publications, inventors produced 12.5 disclosures and 3.3 publications in the last 3 years of the focal patent on average. The number of forward citations were collected from the USPTO database, and, on average, 2.95 forward citations were made based on the focal patent.

3.3.1 Individuals and Motives

Motive is the main theme of this research, and as such, we now begin to describe the relationship between individuals and motives more closely. As explicated earlier, except for the factor loading of the recognition motive, we decided to employ single variables to indicate each motive because of the low internal consistency of factor loadings. Therefore, we have used the following survey options: 1) satisfaction from solving problem, 4) generating value for the firm, and 10) monetary reward. They represent the task motive, the firm motive, and the pecuniary motive, respectively. In addition to the original form of motive variables, we constructed a dummy variable indicating the percentage of inventors who highly regard each motive. In the descriptive statistics, we coded 1 for the responses which report “important,” and “highly important,” otherwise 0.

As shown in Table 3.4, the mean score for the task and firm motives was relatively high compared to the pecuniary motive. Task motive showed the highest mean score of 4.4, and pecuniary motive had the lowest mean score of 2.4. A similar pattern was observed with the dummy variable, in that those who considered task motive as important or very important made up more than 86% of our sample. This was consistent with earlier studies (*c.f.* Sauermann & Cohen, 2010) that showed intellectual challenge with a mean score of 3.75 out of 4 on the Lickert scale; the highest score among motive indicators. Also, the firm motive was highly regarded by approximately 80% of the sample. On the other hand, pecuniary motive was important for only 21%. In Figure 3.2, we have shown variance of the motives with illustrating interquartile range, median and mean score for each indicator. We have observed that inventors with strong task motives as their median score illustrated that the task motive was “very important” based on the survey category. The firm motive turned out to be very strong for our sample, with interquartile ranges from “important” to “very important,” while the recognition motive was important for only 25% of the sample, and interquartile for pecuniary motive ranged from 1) very not important, to 3) neutral.

We briefly illustrated differences in motive by some characteristics in Fig. 3.3 to 3.5. We have not observed much difference in motive between science and engineering majors. For recognition motive, inventors with science backgrounds had marginally higher mean score, and engineers had higher mean scores in pecuniary motive. As to the firm size, the results indicated that there are meaningful differences between small firm employees and non-small firm employees. For example, small-firm employees had higher pecuniary and firm motives than large-firm employees (significant at $p < .01$). On the other hand, large firm employees were more oriented toward the recognition motive compared to the non-large firm employees (significant at $p < .01$). However, there was no significant difference in task motive compared to firm size. We have also compared the mean score of motive to highest degree earned. The result showed that PhD inventors had higher orientation toward recognition motives than non-PhDs.

In addition to the simple descriptive statistics, we ran ordered logit analysis in order to investigate what factors influence the shaping of motives. Determining the antecedents, it has been shown that age, tenure, gender and education are associated with motive (Meyer & Allen, 1991; Mottaz, 1988).

As shown in Table 3.5, level of education is one of the most important factors affecting inventor motives. For example, PhD inventors were more likely to have recognition motives, and less likely to focus on the firm's performance, as were inventors with master's degrees (though weakly significant at $p < .10$). Inventors with master's degrees were also less likely to have task motives. Results also indicated that inventors with bachelor's degrees were likely to be more concerned with a firm's performance than of their own reputations. An inventor's educational background (science or engineering) did not significantly affect their motives. As for those with longer tenure, a task motive decreased as the inventor's experience increased. Recognition motives were also negatively associated with an inventor’s tenure.

In terms of the firm size, inventors from both large and small firms were more likely to have pecuniary motives, compared to inventors from medium-sized firms. In particular, small-firm inventors sought high-monetary rewards and were highly firm-oriented, by a significant margin. In contrast, small-firm inventors were less likely to care about recognition motives, compared to inventors in medium-sized firms.

Mobile inventors who had changed their organizational affiliation within the last 5 years of the focal patent application seemed not to care about their own firm’s performance, but were concerned about their recognition. Female inventors (despite comprising only about 5% of the sample) were more likely to be satisfied by solving problems when inventing than their male counterparts.

Project characteristics showed that patents aimed at creating a new line of business for the firm were more likely to have lead inventors with task motives, compared to the patents resulting from an enhanced existing business line. Also, inventors who were less concerned about the firm’s performance led more projects resulting in patents aimed at cultivating technological seeds.

Table 3.4 Descriptive Statistics

Variable	N	Mean	Std. Dev.	Min	Max
Dependent Variable					
Any Commercialization	983	0.608	0.489	0	1
New Combinations	1175	0.536	0.499	0	1
Solo Inventor	1175	0.249	0.433	0	1
Number of Inventors	1175	2.837	1.860	1	16
Any external co-inventor	1095	0.108	0.311	0	1
Number of external co-inventor	1095	0.143	0.495	0	7
Any Internal co-inventor	1095	0.713	0.453	0	1
Independent Variables					
Satisfaction of solving problem	1175	4.372	0.841	1	5
Generating value for the firm	1175	4.198	0.912	1	5
Ribbon_Factor loading	1175	0.025	0.904	-1.637	1.969
Monetary reward	1175	2.421	1.264	1	5
Percent high_Solving problem	1175	0.866	0.340	0	1
Percent high_Firm performance	1175	0.814	0.389	0	1
Percent high_Ribbon	1175	0.261	0.439	0	1
Percent high_Monetary reward	1175	0.208	0.406	0	1
Science Education background*	1031	0.426	0.495	0	1
Controls					
Technical Significance	970	0.158	0.365	0	1
Size of the Project	1119	21.074	24.211	0.5	97
Inventing Hour	1163	26.345	16.608	0	128
Inventors' Tenure	1140	18.553	9.935	0	49
Bachelor's Degree	1174	0.201	0.401	0	1
Master's Degree	1174	0.250	0.433	0	1
PhD Degree	1174	0.502	0.500	0	1
Seeds	1174	0.230	0.421	0	1
Newline	1174	0.259	0.438	0	1
Large Firm (employee >500)	1175	0.821	0.384	0	1
Medium Firm (100>, <500)	1175	0.065	0.247	0	1
Small Firm (employee <100)	1175	0.114	0.318	0	1
Chemical	1175	0.247	0.432	0	1
Computer & Communications	1175	0.193	0.395	0	1
Drugs & Medical	1175	0.144	0.352	0	1
Electrical & Electronic	1175	0.193	0.395	0	1
Mechanical	1175	0.124	0.330	0	1
Patent Filed Year 2000	1175	0.262	0.440	0	1
Patent Filed Year 2001	1175	0.327	0.469	0	1
Patent Filed Year 2002	1175	0.288	0.453	0	1
Patent Filed Year 2003	1175	0.117	0.321	0	1
Others					
Male	1165	0.953	0.213	0	1
Inventor Age	1148	46.166	9.511	18	81
Number of Invention Disclosures last 3 years	1155	12.534	22.534	0	250
Number of Publications last 3 years	1154	3.347	8.636	0	130
Number of Forward Citation	1175	2.950	4.689	0	50

Weighted by sampling weights

* Science education background does not include social science major, dummy variable 1 indicates science major otherwise 0 for engineering major

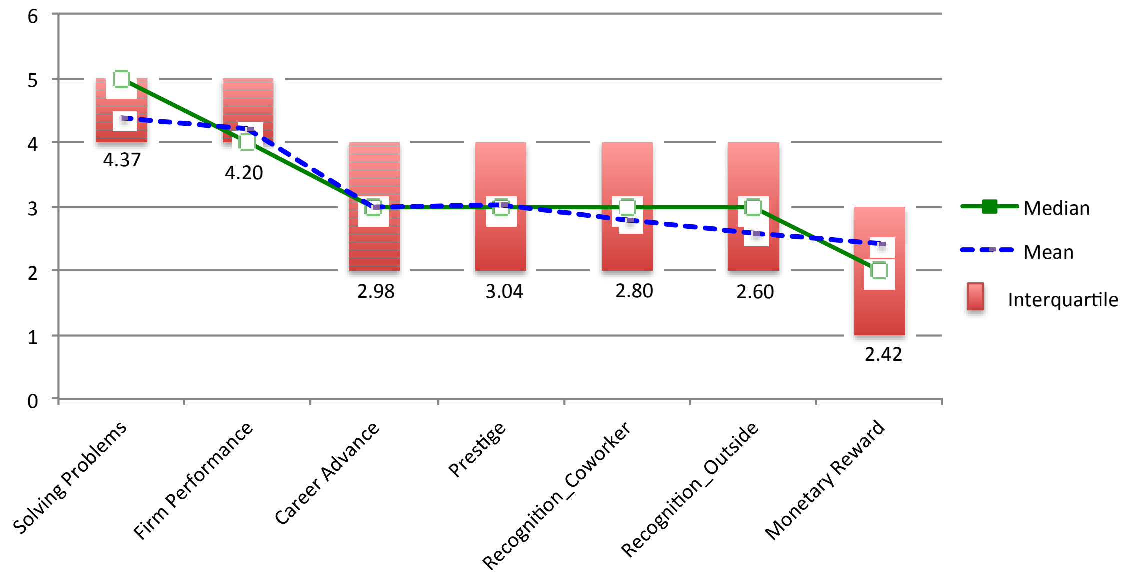
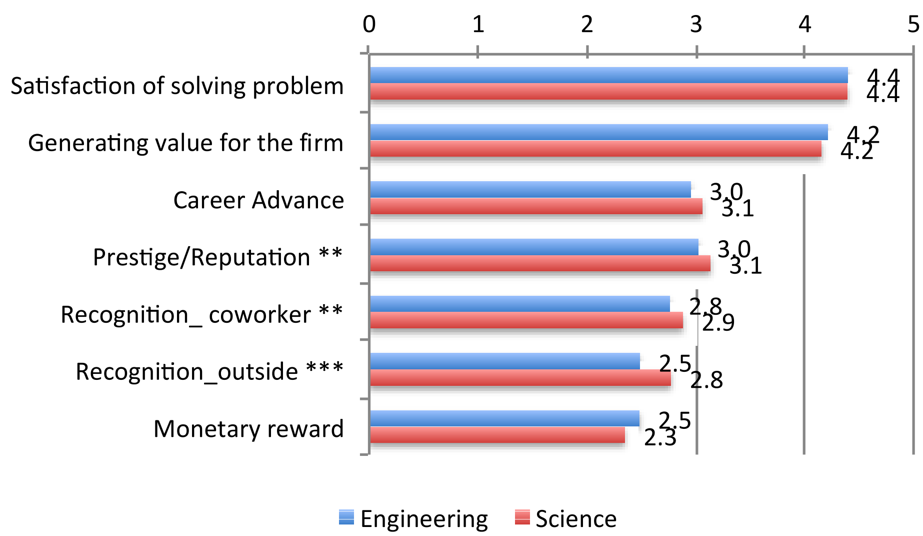


Figure 3.2 IQR, Median, Mean Score of Motives



Weighted by sampling weights, * p<.1, ** p<.05, *** p<.01

Figure 3.3 Mean Score of Motives by Science versus Engineering Background

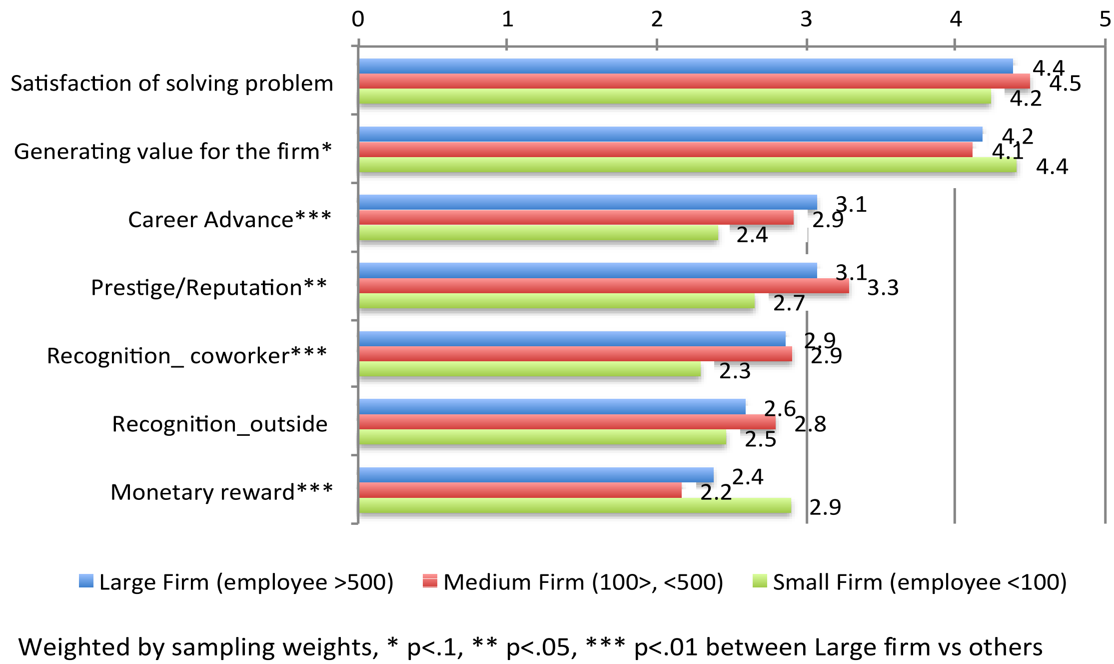


Figure 3.4 Mean Score of Motives by Firm Size

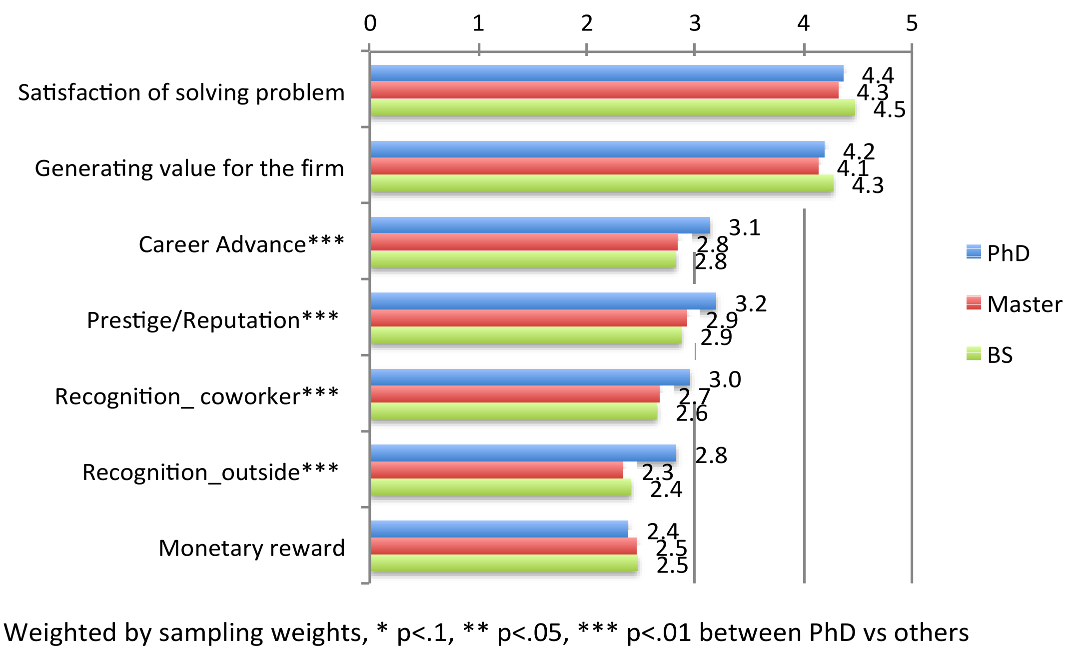


Figure 3.5 Mean Score of Motives by Highest Degree Earned

Table 3.5 Regression Results on Motives

	Solving Problems Ologit	Firm Performance Ologit	Ribbon Regression	Monetary reward Ologit
Tenure	-0.060**	-0.003	-0.021**	-0.033
	(0.010)	(0.022)	(0.010)	(0.021)
Tenure_sq	0.002***	-0.000	0.000**	0.001*
	(0.000)	(0.001)	(0.000)	(0.001)
PhD Degree	-0.086	-0.294*	0.254***	-0.007
	(0.074)	(0.165)	(0.074)	(0.156)
Master Degree	-0.351*	-0.330*	0.011	0.061
	(0.080)	(0.178)	(0.080)	(0.168)
Science Major	-0.016	-0.091	0.034	-0.189
	(0.061)	(0.136)	(0.061)	(0.129)
Large firm (>500)	-0.205	-0.029	-0.026	0.386*
	(0.110)	(0.238)	(0.110)	(0.231)
Small firm (<100)	-0.490	0.745**	-0.367***	1.075***
	(0.136)	(0.308)	(0.136)	(0.293)
Mobile	0.214	-0.355**	0.149**	0.096
	(0.067)	(0.148)	(0.067)	(0.141)
Male	-0.929**	-0.310	-0.087	0.138
	(0.133)	(0.299)	(0.133)	(0.282)
Seeds	0.291*	-0.314**	0.087	0.063
	(0.069)	(0.149)	(0.069)	(0.143)
Newline	0.416***	0.071	-0.032	0.061
	(0.066)	(0.146)	(0.066)	(0.140)
Constant	-6.080***	-4.823***	0.180	-0.517
	(0.500)	(0.500)	(0.193)	(0.414)
Constant	-4.875***	-3.686***		0.595
	(0.459)	(0.459)		(0.414)
Constant	-3.405***	-2.205***		1.722***
	(0.442)	(0.442)		(0.417)
Constant	-1.712***	-0.504		2.863***
	(0.436)	(0.436)		(0.427)
Observations	1,000	1,000	1,000	1,000
Log Likelihood	-1033.55	-1190.83	-1287.22	-1511.46
Wald Chi2	32.92	27.75		28.35
Pseudo R2	0.02	0.01		0.01
R-Squared			0.05	

Robust standard errors in parentheses; Weighted by sampling weights
*** p<0.01, ** p<0.05, * p<0.1

3.3.2 New Combinations

As stated earlier, we found that approximately 54% of the sample had at least one new pair of technology subclasses. Figure 3.6 shows how many new subclass pairings appeared in each patent application year. With the sampling weights, we have not observed any certain trend in recombination by patent application year. In fact, there are more than 100,000 USPC subclasses (Fleming, Mingo & Chen, 2007; Harris, Arens & Srinivasan, 2010), so we can assume 5,000,000,000 possible subclass pairs. When we processed existing technology subclass pairs from utility patents granted from 1975 and filed by 1999, we found 10,789,819 technology subclasses. After creating pairs and removing duplicates, we have found about 440,000 existing technology pairs for the given period. In other words, a little less than 5 billion technology subclass pairs are still unobserved. Therefore, we were not able to observe a decreasing trend in new combinations over the years, as there are simply too many possibilities.

In figure 3.7, we have reported new subclass combinations by technology sectors, as defined by NBER technology sectors. For example, the Chemical sector had the most new subclasses that appeared in our sample, while the Drugs and Medical sector had the least. Then, we examined any differences in the inventor’s level of education attainment. Regarding the highest degree earned, we have not observed a significant difference in the rate of new combinations (Figure 3.8). However, the result showed that inventors with bachelor’s degrees had generated a higher rate of new combinations (56%). Considering the firm size (Figure 3.9), the rate of new combinations was also fairly evenly distributed (differences were not statistically significant).

As to the motives, we compared the rate of patents with at least one new combination between high motives and non-high motives (Figure 3.10). For those who indicated that the motive category was “important” or “very important,” we created a variable specifying high score motive, coded 1, otherwise 0. For the recognition factor loading, we recoded 1 for the high recognition motive in the top 25%, otherwise 0. We found that inventors with a high firm motive were strongly and positively associated with a higher rate of creating new combinations ($p < .01$). This was consistent with previous literature, in that inventors who feel secure in their organizations are more creative, as claimed by Pelz (1976) and Grant and Berry (2011).

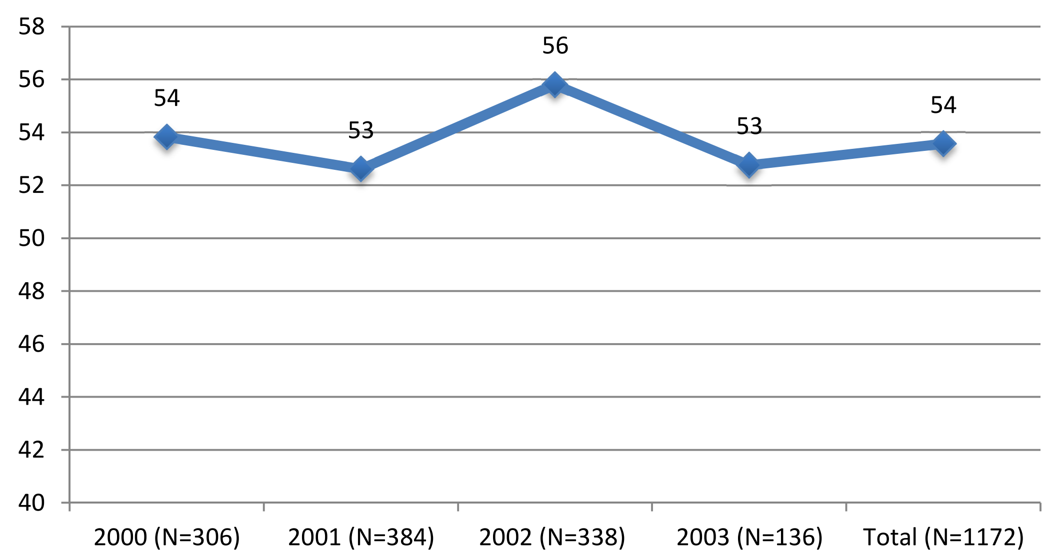


Figure 3.6 Percent of New Combinations by Patent Applied Year

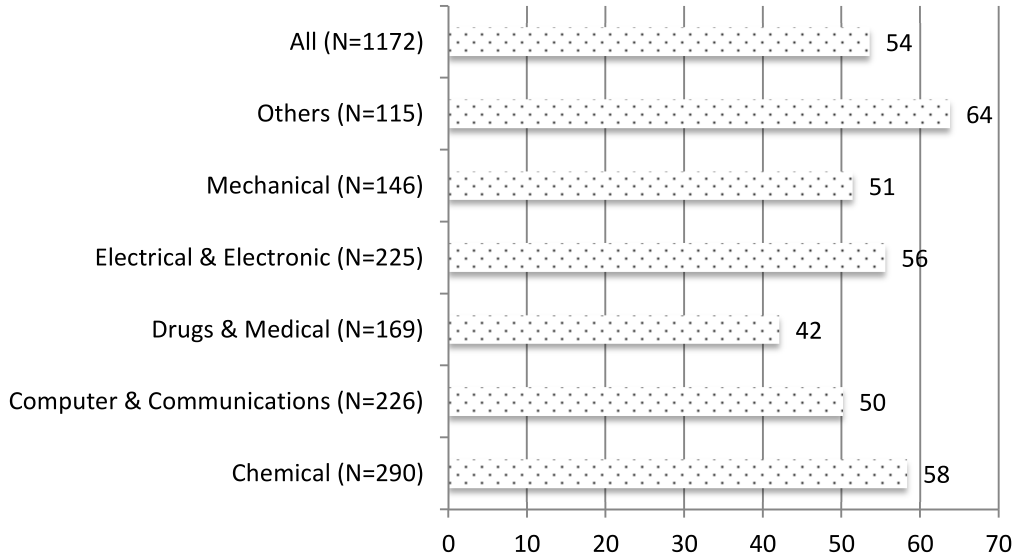


Figure 3.7 Percent of New Combinations by Technology Sectors

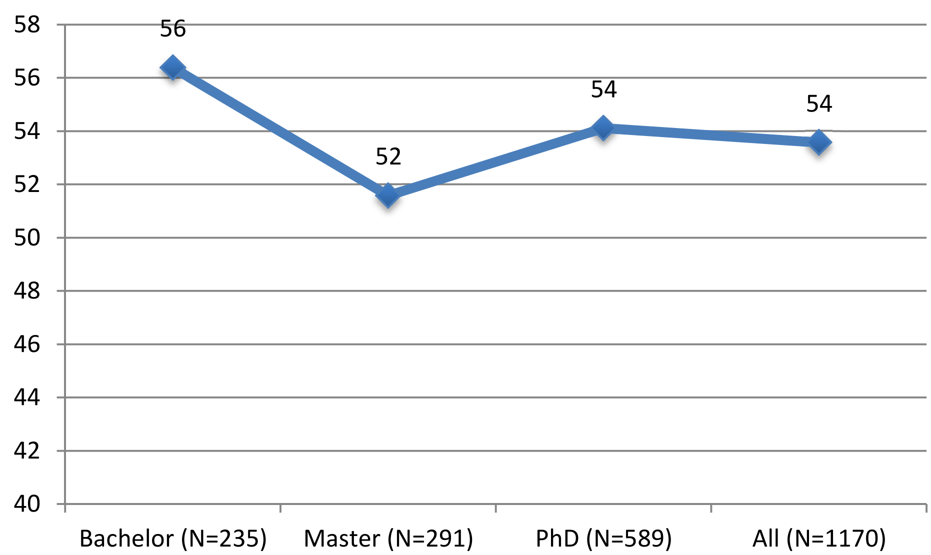


Figure 3.8 Percent of New Combinations by Highest Degree Earned

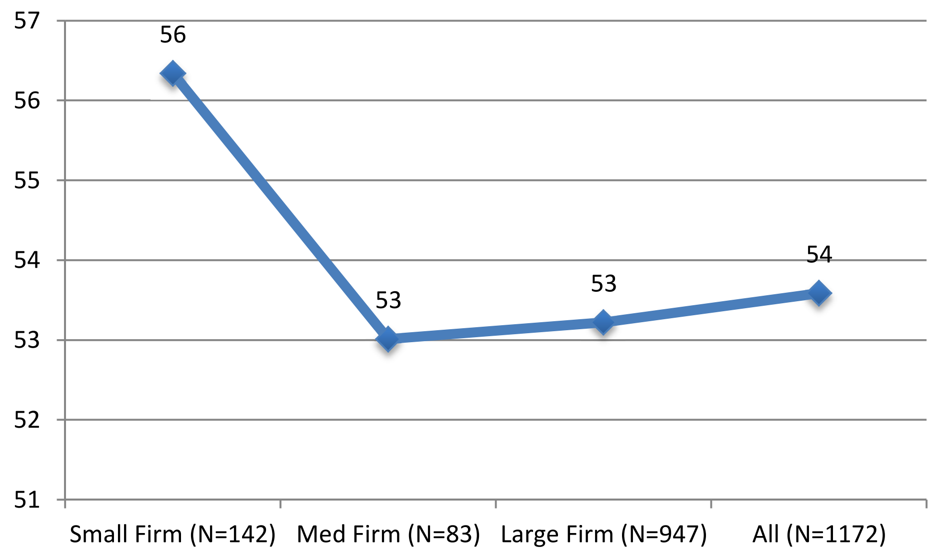
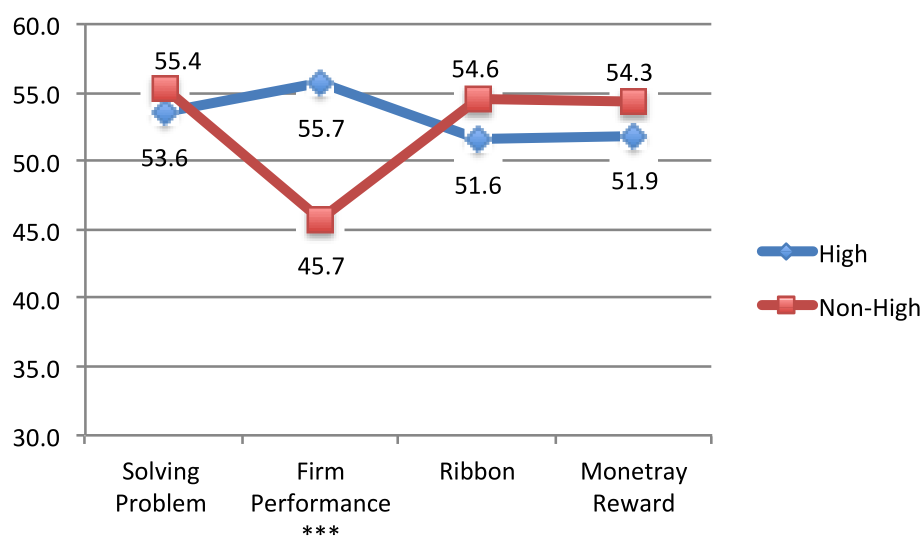


Figure 3.9 Percent of New Combinations by Firm Size



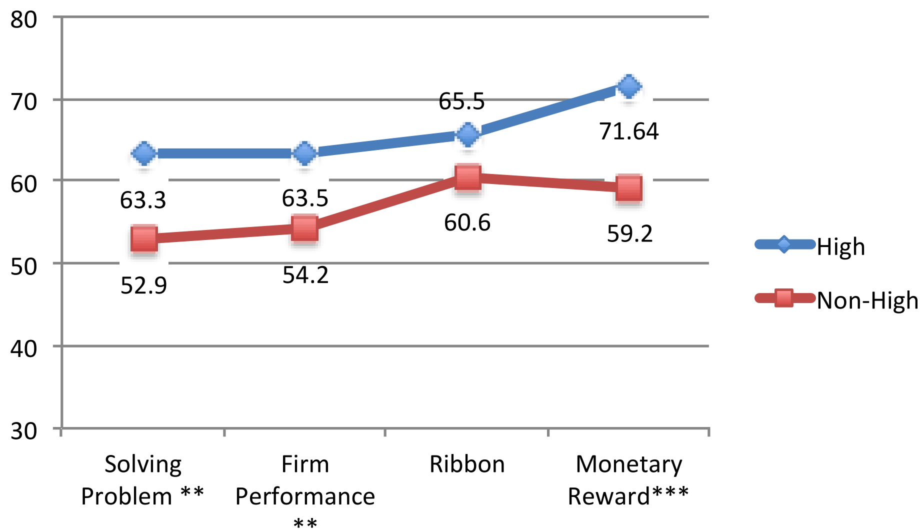
• New combination is significantly different from high motives and non-high motives at **p<.05, and *** p<.01

Figure 3.10 Percent of New Combinations by Motives High versus Non-High

3.3.3 Commercialization

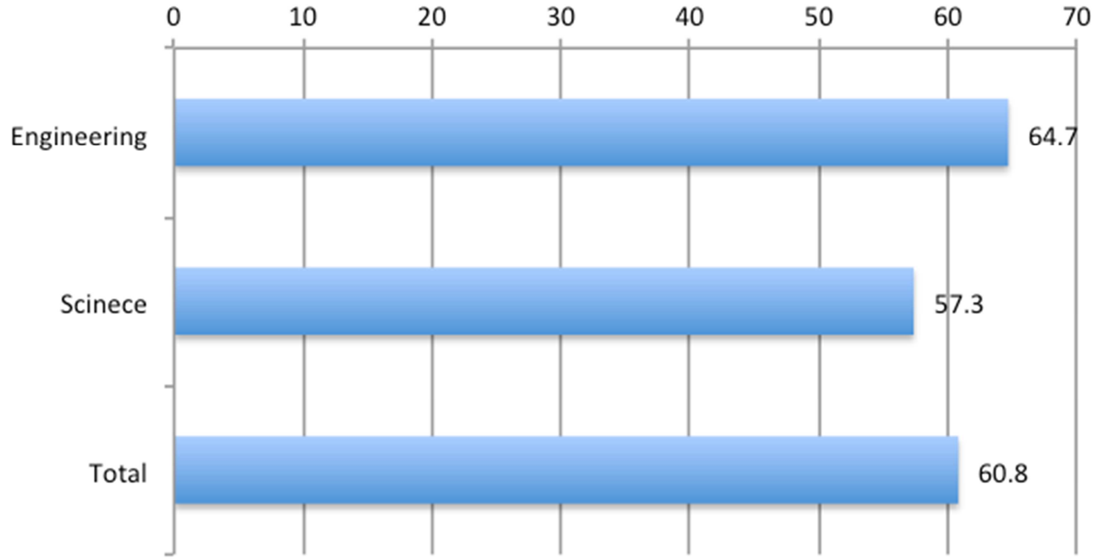
Innovative performance has been measured by whether or not the patent was commercialized. Based on the same data, the GT/RIEIT Inventor survey, Jung (2009) and Huang (2012) have already extensively studied commercialization of the patent. Jung (2009) examined the uses and non-uses of patents at the levels of technology, organization and project. Huang (2012) studied commercialization of the patent at the regional level. This study is built upon their results, and these prior studies are used to generate a base-model of commercialization, from which we can explain the added effects of motive. Accordingly, we have not reported much about descriptive statistics of commercialization. However, this study contributes to the understanding the relation between commercialization and motive, as well as educational background; therefore, we add simple descriptive statistics.

As presented in Figure 3.11, we have observed that motive and commercialization are somewhat significantly related. For example, the results indicated that inventors with higher task, firm performance, and pecuniary motives generated a higher rate of commercialized patents compared to those with low motives in those categories. This was consistent with our hypotheses A, B and D, which expected that task, firm, and pecuniary motives would increase innovative performance. Moreover, it was consistent with Sauermann and Cohen (2010) in that motives toward intellectual challenge, independence and money are positively associated with the number of patent applications generated by scientists and engineers. This was not surprising, as the result suggested that more motivated researchers produce better than their less-motivated colleagues. However, the result still matters in the sense that they suggest different motives have different effects (we have not observed significant association between high recognition motive and commercialization of the patent). As for educational background, we have also observed that inventors with engineering backgrounds had a higher rate of commercialization (Fig. 3.12).



- Commercialization is significantly different from high motives and non-high motives at **p<.05, and *** p<.01

Figure 3.11 Percent of Commercialized Patents by Motive High versus Non-High



** Commercialization is significantly influenced by educational background at $p<.05$.

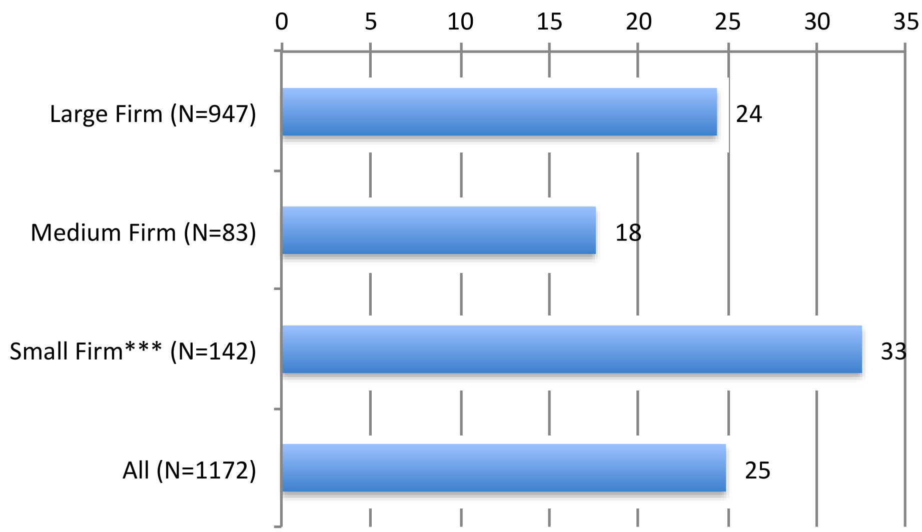
Figure 3.12 Percent of Commercialized Patents by Educational Background

3.3.4 Collaboration

Collaboration can be measured in various ways. Co-assignment, which involves sharing the property rights, and co-inventing have been widely used, in part because they can be measured using publicly available information (Hagedoorn, 2003; Hicks & Narin, 2001). In addition, formal or informal collaboration has been measured in the PATVAL-EU survey (Walsh & Nagaoka, 2009). In the GT/RIETI Inventor survey, we included all of the preceding information in order to thoroughly capture cooperative R&D activities in the U.S. The result showed that about 75% of the sample consisted of “multiple inventors,” i.e. when a patent has two or more inventors. In figure 3.13, we have illustrated the percentage of solo inventor patents by firm size. It was revealed that about

25% of U.S. firm inventions have a single inventor listed in the patent, and small firms have significantly higher rates of solo inventors at about 33%.

The rate of collaborative activities in relation to high versus non-high motives is shown in Figure 3.14. Collaborative activities were broken into solo inventor, external co-invention, and internal co-invention. Overall, we observed that motives affect patterns in no collaboration (measured by solo inventors), external co-invention, and internal co-invention. For example, inventors with high firm motives were less likely to be solo inventors, and more likely to collaborate, especially if employed by the same firm. Also, inventors with high task motives were more likely to be solo inventors, even though the findings were not statistically significant. Results on external co-invention also supported the same trend. The task motive significantly influenced the decision whether or not to externally co-invent, in that those with high task motive were less likely to do so by choice. These findings resonated with our underlying assumption that task motivated inventors are less likely to collaborate. As to other motives, we found that inventors with high recognition and pecuniary motives were more likely to co-invent with entities outside of their company, at 1% significance level.



*** Solo inventor is significantly different between small firms and others at p<.01.

Figure 3.13 Percent of Solo Inventors by Firm Size

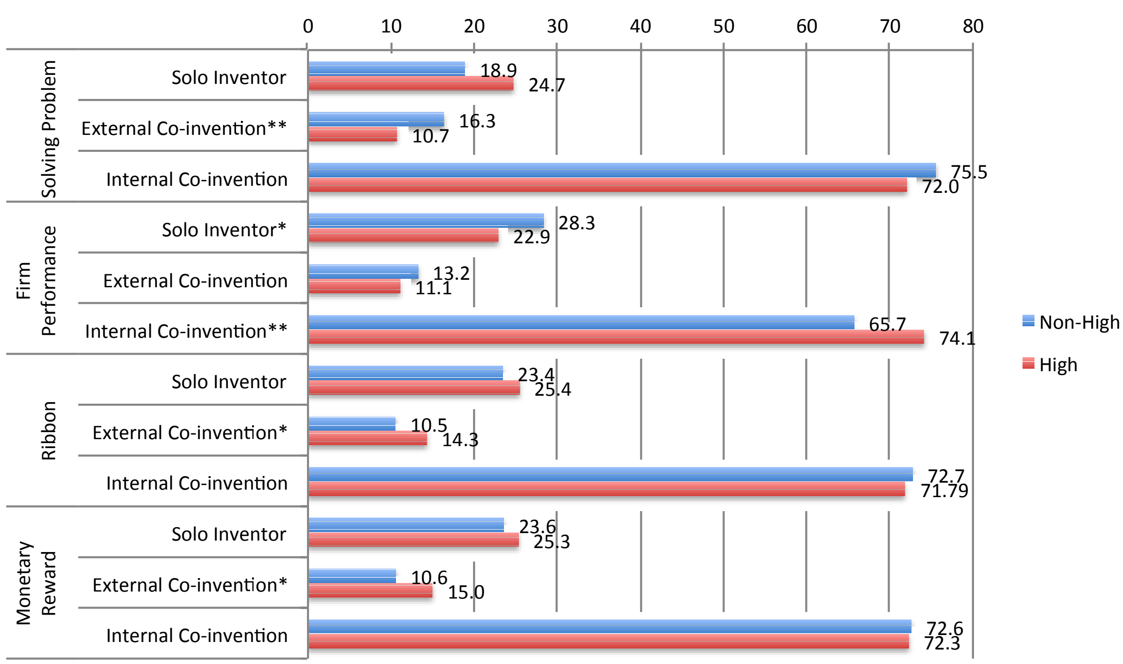


Figure 3.14 Percent of Collaborative Activity by High Motive versus Non-High

3.4 Estimation Method

For the following chapters, we employ two major types of dependent variables: Binary and Count variables. For the dichotomous dependent variables such as commercialization, new combination, co-invention, collaboration, and solo invention, we used logit regression models. The outcome variable is the probability of dependent variables based on a nonlinear function of the predictor variables. The logit model was estimated with a maximum likelihood procedure with the following specification:

$$\ln\left[\frac{\hat{Y}}{1-\hat{Y}}\right] = \alpha + \sum \beta_j X_{ij}$$

Where X_{ij} is the vector of predictor variables and $\hat{Y}$ is the predicted probability of the event.

The other group of outcome variables was measured with count variables (the number of external co-inventors and number of internal co-inventors). Since they are non-negative integer counts with a limited range, the Poisson family of models is used. (Long, 1997) The Poisson model is specified as follows:

$$\Pr(y_i \mid x_i) = \frac{\exp(-\mu_i)\mu_i^{y_i}}{y_i!}$$

Where y is a non-negative count variable, and the left side stands for the probability that x will generate the observed number of dependent variables. Even though we found over-dispersion for count variables (i.e. the number of external co-inventor had a mean of

0.143 and a variance of 0.245), we decided to employ the Poisson model because overdispersion was modest for all count variables.

Additionally, we employed the multinomial logit in order to explain nominal outcomes. For Chapter 6, we recoded collaborative activities into nominal variables, including values such as no co-invention, internal co-invention, and external co-invention. By doing so, we expect that the results concisely illustrate the effect of motives on collaboration. The multinomial had the following specification (Long, 1997).

$$\Pr(y_i = m|x_i) = \frac{\exp(x_i\beta_m)}{\sum_{j=1}^{J}\exp(x_i\beta_j)} \; where \; \beta_1 = 0$$

3.5 Limitation of the Data

One limitation of our dataset was that we were asking a representative inventor to respond for the whole project team. About 70% of the inventions in question had multiple inventors (with a mean of 2.7 inventors). Our sampling strategy targeted the first-listed U.S. inventor. In over 95% of the cases, this was the first inventor (and in 27% of the cases, the only inventor). Thus, we interpreted our sample as representing the “lead inventor” on the patent, and argue that this lead inventor had significant influence on the outcome of the project, such that the lead inventor’s characteristics (including motives, educational background and firm size) can be used to characterize the invention. For example, we coded patents as being generated by task-motivated inventors if the lead inventor (our respondent) reported having a high task motive. There may be additional inventors listed on the patent with other motives, which adds some measurement error to our classification. However, we have tried to mitigate measurement errors as much as possible through conducting robustness checks with a solo inventors-only sample.

CHAPTER 4. MOTIVES AND NEW COMBINATIONS

4.1 Introduction

Creativity can be described as the creation of novel, valuable and nonobvious solutions (Amabile, 1983; 1988). This is very similar to the requirement of the patent: novelty, utility, and non-obviousness. Because of this definition, we can assume that our entire sample is creative, as they have all been patented. However, borrowing the concept of "generative creativity" (Fleming et al., 2007, p. 446), which restricts creativity to the collection of new combinations (Nelson & Winter, 1982; Simonton, 1999), we propose to test the novelty of the patented inventions. We have examined how individual differences influence a patent's usefulness, and whether organizational settings affect the relationship. In this chapter, we test the effect of motives on patent's novelty following the same logic introduced in earlier chapters.

Creativity is sometimes a matter of combination (Hargadon, 2008; Simonton, 1999). Ever since Schumpeter (1934) claimed that innovation is the "carrying out of new combinations," (pp. 65-66), many previous research studies have echoed this notion. Thomas Edison was one famous example of an inventor who put things together and created a world-famous product. As is widely known, Edison was not the first inventor to create the light bulb (Israel, 1998); rather, he successfully combined the electric light, generators, wiring, materials, and business models (Hargadon, 2008).

Accordingly, we developed a creativity measure that indicated whether the technology was recombined and introduced for the first time (Fleming, Mingo & Chen, 2007). It created a unique dataset in addition to the GT/RIETI Inventor survey. Not only is it expected to complement our survey, but it also promotes understanding of the effect of motive on creativity. Using this operationalization, we set up following hypotheses:

> *Hypothesis 1: Task motives are positively associated with the creation of new combinations.*

> *Hypothesis 2: Pecuniary motives are positively associated with the creation of new combinations.*

> *Hypothesis 3. Recognition motives are negatively associated with the creation of new combinations.*

> *Hypothesis 4: Firm motives are positively associated with the creation of new combinations.*

4.2 Regression Results

In this section, we present the regression results, beginning with the binary logit regression with the dichotomous dependent variable “New Subclass Combination.” We considered new combination as a measure of creativity. Regarding motives, we employed an ordinal variable, the original form taken from the survey.

Table 4.1 represents the logit regression results on new combinations. Model 1 is a base model, and only includes control variables. The results showed a positive association between measures of strength of the patents (i.e. the number of claims and number of

USPC subclasses) and having at least one new pair of technology subclasses. Measures indicating strength of patents have been widely used in previous studies, including Jung (2009), who also utilized the GT/RIETI survey (Gambardella, Giuri & Luzzi, 2007; Lanjouw & Schankerman, 2004). These studies focused broader utility, since they described the scope of the patents. Nerkar and Shane (2007) have shown that the number of USPC subclasses was associated with commercialization of academic patents. Note, however, that our dependent variable “new combinations” was created based on USPC subclasses. Therefore, the positive association between the number of USPC subclasses and new combinations suggested that the more subclasses found in the patent, the more novel pairing opportunities exist. As to the interpretation of the result, consequently, we have illustrated the relationship between motives and new combinations after controlling for the numbers of subclasses in the focal patent. Moreover, we conducted a robustness check in the latter section of this chapter by employing the new primary technology subclass combinations. New technology pairs are created between a primary subclass and any of the other subclasses that are listed in the patent. As the first-listed in USPC subclass indication in the patent document, primary subclass had superiority among subclasses, and suggested the main technology associated with the patent. As such, it was a stronger measure of new combination, since primary new combinations only reflected the new combinations closest to the main technology.

Also, as to highest degree earned, we expected that high education levels would encourage a propensity toward creating new combinations. Education brings more experience and the abstract understanding needed for creating recombination (Fleming, 2001; Gruber, Harhoff & Hoisl, 2012), so we expected a positive relationship as the level of education rose. However, in this dissertation, we found that inventors with master's degrees were less likely to come up with new combinations, compared to inventors with bachelor's degrees. Also, we found no significant association between PhD inventors and recombination compared to bachelor's level inventors.

In terms of firm size, the results evidenced that small-firm inventors were more likely to come up with a new technology subclass combination compared to medium-firm inventors. We found no significant difference between large-firm researchers and medium-firm researchers.

With motive variables in the model, we found some interesting results. We expected that task-oriented motives would increase the creation of new combinations. In this dissertation, we measured creativity by operationalizing it as new subclass combinations. Overall, we found positive effects of task, pecuniary and firm motives on the creation of new combinations, even though they were not statistically significant. As illustrated in models 2 and 6, we have not found any significant relationship between task motives and the creation of recombinations, whether regressed with or without other motive variables. The pecuniary motive also turned out to be positive, but a non-significant factor on creating new combinations. Previous literature suggested a mixed effect of pecuniary motive, in that it could decrease creative behavior (Amabile, 1988; 1996; Farr & Ford, 1990; Fleming, 2001; Gruber, Harhoff & Hoisl, 2012) or could have no or even positive effect on innovative activities (Sauermann & Cohen, 2010). Our findings showed no significant effect, so we can suggest at least that pecuniary motives do not decrease creative activity.

We hypothesized that recognition motives would be negatively associated with the creation of new combinations in Hypothesis 3. Because of the importance of social approval when producing a new idea (Simonton, 1999), we expected that recognition motives would be negatively associated with creative activity. Given that recognition motives particularly rely on social approval, we assumed that risk associated with creativity would affect recognition-driven inventors more strongly than it would inventors with other motives. Recognition factor loading was used to capture instances of the recognition motive. As expected, we found significantly negative associations between recognition and the generation of new technology subclass combinations.

Firm motive, measured by “generating value for the firm,” had a positive association with the dependent variable. We expected that it would encourage the creation of recombination, and the result upheld our hypothesis 4. Even though we have not found a significant effect of firm motives in Models 3 and 6, the effect of firm motives is close to the conventional significance, level, with z-statistics over 1.0. In other words, inventors aligned strongly with a firm motive were more likely to create new combinations. Based on previous literature (Andrews, 1979; Andrews & Farris, 1967; Oldham & Cummings, 1996; Shalley, 2008), we conjectured that inventors with a high firm motive feel secure in being a member of an organization, therefore allowing their creativity to increase. Moreover, this aligned with the finding of Grant and Berry (2011) in that prosocial motivation – the desire to help others, and to maintain membership with a group of people they care about – strengthens creativity.

Questioning that task and pecuniary motives show no significant effect on new combinations, we hypothesized a mediating effect of work hours. Previous studies have found that intrinsic motives increase the work effort (Fredrickson, 1998; Levin & Stephan, 1991; Sauermann & Cohen, 2010). In general, mediation can be said to occur when: the independent variable significantly affects the mediator; the independent variable significantly affects the dependent variable in the absence of the mediator; the mediator has a significant unique effect on the dependent variable; and the effect of the independent variable on the dependent variable shrinks upon addition of the mediator to the model. Therefore, we employed Sobel-Goodman tests to examine whether a mediator carries the influence of an independent variable to a dependent variable (Sobel, 1982). What we found was that the mediation effect of work hours was small across motives (i.e. ranged from less than 10% to 0%). Direct influence of task motives on work hours was positively significant, but t-value was 1.85. This confirmed previous literature in that work hours were affected by task motives, but our result was not as significant as earlier studies. Therefore, we do not suspect that a mediation effect causes no effect on motives in regards to creating new combinations.

Another interesting result was that, with all motives included in the model (Table 4.1, Model 6), we have found that a project's goal of "creating a new line of business" decreases the generation of new combinations compared to that of "enhancing an existing line of business." In other words, an invention that came out of a project aimed at enhancing an existing line of business was more likely to produce new technology subclass combinations. A technology combination that has never been introduced may seem to be a "breakthrough," but our results indicated otherwise.

Table 4.1 Regression Results on New Combinations

	Dependent Variable: New Combination (Y/N)					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Controls Only	Task Only	Firm Only	Recognition Only	Pecuniary Only	All Motives
Solving Problem		0.105				0.161
		(0.104)				(0.106)
Firm Performance			0.137			0.142
			(0.091)			(0.090)
Recognition				-0.174		-0.253**
				(0.108)		(0.120)
Monetary Rewards					0.033	0.085
					(0.070)	(0.077)
Technical Significance	0.011	0.008	0.008	0.027	0.010	0.024
	(0.088)	(0.088)	(0.087)	(0.088)	(0.088)	(0.088)
Size of Project	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Inventing Hour	-0.000	-0.001	-0.000	0.000	-0.000	-0.001
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Number of Inventors	-0.005	-0.001	-0.007	-0.006	-0.005	-0.003
	(0.044)	(0.044)	(0.044)	(0.045)	(0.044)	(0.044)
Inventor's Tenure	-0.018	-0.016	-0.018	-0.022	-0.017	-0.019
	(0.032)	(0.031)	(0.032)	(0.032)	(0.032)	(0.032)
(Inventor's Tenure)^2	0.000	-0.000	0.000	0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Master Degree	-0.477*	-0.465*	-0.464*	-0.469*	-0.479**	-0.440*
	(0.243)	(0.243)	(0.244)	(0.243)	(0.243)	(0.245)
PhD Degree	-0.325	-0.318	-0.306	-0.283	-0.321	-0.227
	(0.210)	(0.209)	(0.209)	(0.212)	(0.210)	(0.211)
SEEDS	-0.197	-0.215	-0.177	-0.176	-0.200	-0.185
	(0.244)	(0.243)	(0.244)	(0.244)	(0.245)	(0.243)
NEWLINE	-0.322	-0.338	-0.325	-0.330	-0.331	-0.381*
	(0.207)	(0.209)	(0.206)	(0.205)	(0.205)	(0.205)
Number of claims	0.012**	0.012**	0.012**	0.012**	0.012**	0.013**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Number of USPC class	0.673***	0.675***	0.672***	0.682***	0.672***	0.685***
	(0.066)	(0.067)	(0.067)	(0.065)	(0.066)	(0.066)
Large firm (>500)	0.176	0.185	0.171	0.161	0.169	0.140
	(0.332)	(0.330)	(0.329)	(0.333)	(0.333)	(0.328)
Small firm (<100)	0.799*	0.843**	0.763*	0.701*	0.778*	0.634
	(0.409)	(0.411)	(0.409)	(0.413)	(0.412)	(0.420)
Constant	-4.976***	-5.440***	-5.559***	-5.050***	-5.058***	-6.605***
	(1.102)	(1.222)	(1.191)	(1.095)	(1.105)	(1.309)
Technology Class	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Patent Filed Year	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	921	921	921	921	921	921
Log Likelihood	-636.02	-636.02	-636.02	-636.02	-636.02	-636.02
Wald Chi2	151.89	150.71	150.12	166.68	151.79	166.09
Pseudo R2	0.29	0.29	0.30	0.30	0.29	0.30

Robust standard errors in parentheses; Weighted by sampling weights
*** p<0.01, ** p<0.05, * p<0.1

4.3 Robustness Check

Because we attributed one inventor's motive to the whole invention, we might introduce some measurement error. In order to examine the robustness of our findings, we conducted the same analysis only for the patents generated by solo inventors. As represented in Table 4.2, we are confident in our finding that only a firm motive positively affects the creation of new combinations. Aside from firm motives, solo inventor's task, pecuniary or recognition motives reflected no significant relationship with new combination creation.

Also, as described earlier, we ran regression analysis on primary technology subclass new combinations. Here, this stands for new technology pairs created between a primary subclass and any of the other subclasses listed in the patent. As the first-listed in USPC subclass indication in the patent document, primary subclass had superiority among subclasses, and suggested the main technology associated with the patent. Therefore, it was a stronger measure of the new combination, since primary new combinations only reflected the new combinations closest to the main technology. As described in Table 4.2, our findings were similar to those in Table 4.1.

Table 4.2 Regression Results on New Combinations, Solo Inventors Only, and on Primary New Combinations

	Dependent Variable: New Combination (Y/N), Solo inventors					Dependent Variable: Primary New Combination (Y/N)				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
	Task Only	Firm Only	Recognition Only	Pecuniary Only	All Motives	Task Only	Firm Only	Recognition Only	Pecuniary Only	All Motives
Solving Problem	0.255				0.235	0.012				0.063
	(0.252)				(0.257)	(0.096)				(0.099)
Firm Performance		0.292			0.285		0.171*			0.184*
		(0.202)			(0.203)		(0.096)			(0.096)
Recognition			0.217		0.129			-0.188*		-0.231**
			(0.227)		(0.273)			(0.103)		(0.117)
Monetary Rewards				0.128	0.048				-0.013	0.032
				(0.168)	(0.198)				(0.074)	(0.082)
Base Model	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Technology Class	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Patent Filed Year	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	225	225	225	225	225	921	921	921	921	921
Log Likelihood	-154.33	-154.33	-154.33	-154.33	-154.33	-570.24	-570.24	-570.24	-570.24	-570.24
Wald Chi2	122.43	123.52	122.31	121.97	125.19	96.63	99.17	97.88	96.99	102.32
Pseudo R2	0.40	0.40	0.40	0.40	0.41	0.14	0.14	0.14	0.14	0.15

Robust standard errors in parentheses; Weighted by sampling weights

*** p<0.01, ** p<0.05, * p<0.1

4.4 Conclusion and Discussion

In summary, we found that the following were positively associated with new combinations: task, pecuniary and firm motives, a project that aims to enhance an existing line of business, and small-firm inventors with bachelor's degrees. These findings suggested that how we measured creativity may have captured exploitation rather than exploration. Stemming from March (1991), while exploration relates to things captured by terms such as search, variation, experimentation, innovation and the pursuit of new knowledge, exploitation relates to refinement, selection and reuse of existing knowledge and resources. They share attributes such as learning, improvement, and acquisition of new knowledge (Gupta, Smith & Shalley, 2006), but exploitation focuses on an existing technological trajectory (Benner & Tushman, 2002). Given that our creativity measure was operationalized as new combinations of technology subclasses, we can say that new combinations are based on an existing technological trajectory because they are an assemblage of existing technology subclasses. Our results resonated with this differentiation, in that a project aimed at improving an existing line of business was positively associated with new combinations. Based on inventors and/or a firm's existing competencies, new combinations are created.

Moreover, the positive relationship between firm motives, bachelor's degrees and new combinations supported our argument that new combinations capture exploitation. Since exploitation entails repetition and incremental changes based on established knowledge, bachelor's degree-holding inventors who are highly committed to their firm are expected to continue engaging in those activities. Conventionally, higher-degree holders have been more responsible for exploring new projects because they are known to have an abstract understanding of problem solving (Gruber et al., 2012). Additionally, employees with a high commitment to the organization were reported to have a lower turnover rate (Porter et al., 1974), and those with seniority in the organization were considered to have redundant knowledge, routines and paradigms (March, 1991). Therefore, we claim that our results indicate that the creation of new combinations are closer to minor creativity than those considered as technological major “breakthroughs” (Mumford & Gustafson, 1988).

Previous literature has been more focused on how an idea is transferred and diffused than the process of idea generation (Damanpour, 1991; Fleming, 2001; Rogers, 1995). This dissertation adds to the discussion of how new ideas are generated, with particular interest in the individual differences. We found a positive effect of the task, pecuniary and firm motives on the creation of new combinations (even though they were not statistically significant). Also, the results suggested that recognition motives negatively influenced the creation of new combinations.

These findings allude to the importance of attachment to the organization for industry scientists and engineers. We suspected that attachment to the firm mattered in increasing creativity, because they do not consider themselves as “estranged labor” (Marx, 1932). This sense of belonging can develop into commitment to the firm when, for example, supervisors seem to really listen to their employees, and their opinions are heard and considered when the company makes a decision (Andrews & Farris, 1967). Free from feelings of alienation or isolation, employees are able to satisfy their need for security, and in this safe environment, enhance their creativity.

Therefore, this dissertation can contribute to the managerial implication, in that firms need to develop policies that reduce employee feelings of isolation or estrangement. Perceived organizational support (POS) (Podsakoff et al., 2000), perceptions of procedural justice, and participation in the decision-making process (Konovsky, 2000) have been reported to create a work environment that induces commitment to the organization. In order to build a sense of belonging, for example, Samsung has created a strong sense of cohort with fellow employees who got hired in the same year through the summer-camp-like program that began their employment. Also, increased mentorship in addition to desirable supervisory relationships would be a plus. Even though the system can generate “estranged labor,” individually targeted policy can mitigate this effect.

It is also worth noting that we found a significantly negative association between recognition motives and new combinations. The results supported the assumption that there is risk associated with creativity, and this could hamper the creativity of R&D employees. Considering that recognition-driven inventors are more likely to depend on the approval of others, they can be more apprehensive about differences, and creating new ideas. In the firm level, creating work environments that protect R&D employees from encountering hard criticism might help to encourage recognition-driven inventors to come up with new ideas. Also, if inventors acknowledge that unusual inventions can be taken seriously under any circumstances in their work setting, recognition-driven R&D personnel would be less likely to worry about losing their reputation, which, in turn, would increase creativity in inventors with recognition motives.

CHAPTER 5. MOTIVES AND COMMERCIALIZATION OF THE INVENTION FOR SCIENTISTS AND ENGINEERS

5.1 Introduction

Employee motives have been identified as an important factor for generating high value innovation. Prior research findings indicated the importance of intrinsic motivation, in that researchers performed better when motivated by the task itself, and were satisfied by solving technical questions (Amabile et al., 1994; Sauermann & Cohen, 2010; Sauermann & Stephan, 2010). Empirical work showed that industry researchers chose companies providing a “scientific work environment,” even sacrificing their salary to do so (Stern, 2004). Some experimental work in social psychology, on the other hand, indicated that performance was a function of the interaction between monetary rewards and intrinsic motivation (Amabile, 1996; Deci, Koestner & Ryan, 1999; Frey & Jegen, 2001; Wiersma, 1992). Specifically targeted toward the motives of the S&E workforce, some studies also showed that both task and pecuniary motives played roles in promoting productivity (Sauermann & Cohen, 2010; Sauermann & Stephan, 2010; Stephan & Everhart, 1998; Stephan & Levin, 1992). Following the prior work that examined the effect of motivation on performance in terms of salary (Stern, 2004) and productivity (i.e., the number of patents generated) (Sauermann & Cohen, 2010), we examined the effect of motives on the rates of commercialization of inventions.

The relationship between motivational differences and educational background, especially under industrial settings, has received limited attention. Given the different natures of research and development regarding the novelty involved in each work, it was conjectured that different forms of motivation might operate in different work settings. It was claimed that engineers and scientists hold different types of motivation (Kerr & Von Glinow, 1977; Miller, 1967; Pelz & Andrews, 1976; Ritti, 1968); engineers were more likely to assimilate the goals of the enterprise, while scientists were focused on satisfying their needs for scientific achievement. However, most of these studies were conducted decades ago. Also, the possible motivational differences derived from researcher educational backgrounds had been almost unexplored.

To address this gap in research, we would like to examine firstly the influence of motives on innovative performance, and secondly, the difference in motives by educational background, and how these interact to affect performance. Innovative performance was measured by the commercialization of the invention. The first research question entailed the following set of hypotheses:

> *Hypothesis A: Task motives are positively associated with commercialization of the invention.*
>
> *Hypothesis B: Pecuniary motives are positively associated with commercialization of the invention.*
>
> *Hypothesis C: Recognition motives are positively associated with commercialization of the invention.*

Hypothesis D: Firm motives are positively associated with commercialization of the invention.

We then investigated whether educational background makes any difference in commercialization of the invention, in relation to motive. Disciplinary training was measured as a proxy for educational background, and inventors were categorized as scientists and engineers based on training. Following the distinction between cosmopolitans and locals (Gouldner, 1957b; 1958; Merton, 1957), we set up the following hypotheses:

Hypothesis E: The improvement in innovation performance associated with recognition motives would be larger for inventors with science backgrounds than for those with engineering backgrounds (interaction effect).

Hypothesis F: The improvement in innovation performance associated with firm motives would be larger for inventors with engineering backgrounds than for those with science backgrounds (interaction effect).

5.2 Regression Results

5.2.1 Motives and Commercialization of the Invention

In this section, we present the regression results, beginning with the binary logit regression with dichotomous dependent variable "commercialization," a proxy of an innovative performance.

Table 5.1 represents the logit regression results predicting rates of commercialized activities based on the focal patent. Model 1 is the basic model with control variables.

The results showed a positive effect of the technical significance of the patent on its commercialization. As to the inventor's tenure, it indicated a weak but negative association with commercialization. Previous research based on life-cycle models showed that scientists' output, measured by publication, peaked during the career and declined over time (Levin & Stephan, 1991). As Levin and Stephan mentioned, the model is compounded with age and cohort effect, which rendered it hard to untangle. This dissertation employed tenure after graduation in order to measure the skills and knowledge of the individual inventor,. However, we found no significant association.

In addition, the base model indicated a negative association between an inventor's education level and commercialization. In particular, PhD degree-holders were less likely to come up with a commercialized invention when compared to bachelor's degree-holders. We observed no significant relationship of master's degree-holders on the commercialization of a patent. Also, in terms of the project characteristics, we found that inventions with the goal of "enhancing the technology base of the firm" or "long-term cultivation of technology seeds" were less likely to be commercialized, compared to inventions with the goal of "enhancing existing lines of business." Cohen and Levinthal (1990) found that inventions built upon existing businesses were more likely to be commercialized because they are grounded on/by existing capabilities. Our findings supported this. Regarding the size of the firm, our results indicated that larger firms were less likely to commercialize the invention (at $p < .05$) compared to medium-sized firms (employees between 100 and 500).

When adding motive variables, we found some evidence to support our hypotheses. It had been expected that task motives would be positively associated with the commercialization of the invention in hypothesis A. We operationalized the task motive by using the survey category “satisfaction from solving problems.” The result in models 2 and 6 indicated that, in general, task motives were positively associated with commercialization. The effect of task motive was significant after controlling for technical significance, strength of the patent, inventors’ level of education, firm size, and project size. It suggested that inventions generated from inventors with task motives were more likely to be commercialized, no matter how critical the invention was. Also, regardless of the amount of resources invested, inventions produced with task motives were more likely to be put on the market. The negative effects of PhD inventors and seed project variables on patent commercialization remained the same across models. Note, however, that work hours were reported to be positively associated with commercialization of the patent, even though the significance was at $p < .10$.

Pecuniary motives also positively influenced commercialization, supporting hypothesis B. The results in model 5 indicated that pecuniary motives had positive effects on innovative activities (at $p < .05$) after controlling for the value and strength of the patent, investments put into the patent, and inventors’ individual characteristics (see Table 5.1). Even though the significance reduced when introducing all motives in the model, it was consistent with previous studies in that both task and pecuniary motives were important factors in positively affecting commercialization of the inventions (Sauermann & Cohen, 2010; Chen et al., 1999). In other words, both autonomy to conduct research of their interests and financial security were essential for R&D employees. In particular, our findings were meaningful given that the ultimate goal of the firm is profit. Furthermore, we directly measured the effect of the pecuniary motive on commercialization of the patent, which can generate profit for the company. In this regard, this dissertation complements previous literature by suggesting a systematic reward structure for inventors in order to stimulate the commercialization of the invention of the firm.

As for the recognition motive, we also expected that it would be positively associated with the commercialization of the invention. We operationalized the recognition motive by using factor loading of indicators like “career advance,” “prestige/reputation,” “recognition from co-worker,” and “recognition from the field.” As opposed to hypothesis C, our results showed that inventors who cared about rewards, ribbons and recognition were not significantly associated with the likelihood of commercialization (See Table 5.1, Model 4 & 6). We suspect this result is due to the fact that inventors already have their recognition by having their name on the patent. The aforementioned interview conducted by Judge et al. (1997) suggested that what inventors want is the title, not the money. Also, Friedlander (1971) suggested that professionally oriented research scientists were more likely to regard their organizations as a place that offered them facilities and opportunities for pursuing their work. Hence, appropriation of the patent would not matter for recognition-oriented inventors. Rather, they are more likely to take advantage of what organizations provide them, and try to obtain recognition out of it.

Aoshima and Kubota (2011) illustrated a good example of the aforementioned proclivity by comparing the cases of Fujitsu and IBM. In developing ArF resistant materials, IBM was intentionally striving to improve resolution, while Fujitsu was focused on the commercialization process. Improvement of the resolution was a perfect indicator for proclaiming IBM's technological advantage inside and outside of the company. Based on the research outcome, IBM employees were also actively participating in academic conferences to demonstrate their superiority. However, when it came to commercialization, Fujitsu prevailed since it acknowledged the problems associated with the development process. Therefore, instead of focusing on improving the technology, Fujitsu geared their efforts toward easy development. It was noted by a Fujitsu employee that making ArF resistant materials as a resin was the path of least resistance because it was "easy to manufacture and commercialize" (p.12). In the market, IBM was not as successful as Fujitsu, regardless of their technological edge and reputation in the field. Taking this example to our dissertation, we can imagine that recognition-oriented inventors would not care whether the invention was easy to commercialize; rather, they would focus on gaining a reputation inside and outside of the firm by having the title in patents, presentations, and publications.

In hypothesis D, we expected that firm motives would be positively associated with the commercialization of the invention. The concept of the firm motive is considered to be equivalent to organizational commitment in this dissertation, and was measured by the survey category "generating value for the firm." In models 3 and 6, our findings confirmed hypothesis D, in that patents made by firm-oriented inventors were more likely to be commercialized. As a member of an organization, inventors fulfilled their need for security, and reduced uncertainties around them (Weick, 1995). In turn, this fostered commitment to the organization, and its value was shared among its members (Ashforth et al., 2008). Therefore, we suspected that inventors prioritize firm's performance in order to maintain their sense of belongingness and to prove their loyalty. Due to their high understanding of the capability of the firm, their inventions could turn out to produce a higher chance of patent commercialization.

At the same time, we suspected firm motives would reflect in some way the pecuniary motive. For example, many companies implement a system called an “Employment Stock Purchase Plan,” which allows employees to purchase stock in their firm at a relatively cheaper price (about 10-15%) than what is offered on the open market. This gives employees a chance to capture financial returns when their firm performs well in the market. This system latently helps align employees’ goals to the firm’s performance, as employees benefit from the firm’s good performance in the market. In other words, even though they do not indicate monetary rewards, these financial benefits may help inventors to generate heightened commercialization of the invention through an interesting strategy of the firm. Since we explicitly asked respondents to rate whether monetary reward was an important motive for them, we assumed they were exclusive categories. However, in order to check the robustness of our findings, we employed a correlation analysis on motives against firm size. As indicated in Table 5.3, we found that firm motives and pecuniary motives had a strong positive association with inventors in small firms and startup firms (defined as younger than five years old), as opposed to large firms. The strength of the correlation increased from .08 for overall to .22 and .26, respectively, for small firms and startups. Any correlation between pecuniary and firm motives disappeared only for the large firm employees. This result suggested that smaller-firm inventors could conflate their pecuniary and firm motives, since the future of both firm and inventor is jointly affected by the success of the firm.

Table 5.1 Regression Results on Commercialization of the Invention

	Dependent Variable: Commercial use of patented invention (Y/N)					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Controls Only	Task Only	Firm Only	Recognition Only	Pecuniary Only	All Motives
Satisfaction of solving problem		0.245**				0.235**
		(0.105)				(0.111)
Generating value for the firm			0.216**			0.208**
			(0.095)			(0.097)
Recognition				0.153		0.034
				(0.100)		(0.113)
Monetary Rewards					0.145**	0.127*
					(0.069)	(0.075)
Technical Significance	0.518***	0.513***	0.513***	0.503***	0.521***	0.508***
	(0.085)	(0.086)	(0.085)	(0.085)	(0.086)	(0.088)
Size of Project	0.002	0.002	0.003	0.002	0.002	0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
ln(work hours)	0.487	0.503*	0.448	0.518*	0.532*	0.514*
	(0.309)	(0.298)	(0.320)	(0.308)	(0.301)	(0.304)
Number of Inventors	0.004	0.011	0.000	0.008	0.002	0.007
	(0.044)	(0.044)	(0.043)	(0.044)	(0.044)	(0.044)

Table 5.1 continued

Inventor's Tenure	-0.014	-0.008	-0.012	-0.010	-0.007	0.001
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
$(\text{Inventor's Tenure})^2$	0.000	-0.000	0.000	0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Master Degree	-0.256	-0.249	-0.210	-0.264	-0.257	-0.209
	(0.249)	(0.248)	(0.254)	(0.250)	(0.252)	(0.255)
PhD Degree	-0.574***	-0.581***	-0.554***	-0.619***	-0.567***	-0.565***
	(0.213)	(0.212)	(0.213)	(0.216)	(0.213)	(0.215)
SEEDS	-0.583***	-0.636***	-0.556**	-0.606***	-0.590***	-0.619***
	(0.217)	(0.217)	(0.217)	(0.217)	(0.219)	(0.218)
NEWLINE	-0.337	-0.370*	-0.330	-0.339*	-0.360*	-0.384*
	(0.205)	(0.205)	(0.208)	(0.206)	(0.207)	(0.209)
Number of USPC subclasses	-0.010	-0.008	-0.011	-0.011	-0.012	-0.010
	(0.026)	(0.026)	(0.027)	(0.027)	(0.026)	(0.027)
Number of claims	-0.003	-0.003	-0.003	-0.003	-0.002	-0.003
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Large firm (>500)	-0.677**	-0.642*	-0.675**	-0.644*	-0.709**	-0.661*
	(0.343)	(0.344)	(0.343)	(0.341)	(0.338)	(0.341)
Small firm (<100)	0.723	0.846*	0.664	0.825*	0.619	0.713
	(0.441)	(0.453)	(0.440)	(0.444)	(0.438)	(0.453)
Constant	-0.975	-2.074	-1.825	-1.064	-1.460	-3.300**
	(1.504)	(1.530)	(1.579)	(1.499)	(1.495)	(1.630)
Technology Class	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Patent Filed Year	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	789	789	789	789	789	789
Log Likelihood	-527.16	-527.16	-527.16	-527.16	-527.16	-527.16
Wald Chi2	85.94	87.27	88.46	86.65	84.28	87.17
Pseudo R2	0.11	0.11	0.11	0.11	0.11	0.12

Robust standard errors in parentheses; Weighted by sampling weights
*** p<0.01, ** p<0.05, * p<0.1

Table 5.2 Correlation Between Motives, Invention Disclosures, Firm Size, and Work Hours

	Variables	Mean	Std.Dev.	1	2	3	4	5	6	7		
1	Solving Problems	4.372	0.841									
2	Firm Performance	4.198	0.912	0.0337								
3	Recognition	0.025	0.904	0.2048 ***	0.0599 **							
4	Monetary Rewards	2.421	1.264	0.0531 **	0.021	0.2999 ***						
5	Invention Disclosures	11.174	18.111	0.0131	0.0476 **	-0.009	0.0477 **					
6	Large firm (>500)	0.821	0.384	0.0419 *	0.0629 ***	0.1026 ***	-0.0953 ***	0.0745 ***				
7	Small firm (<100)	0.065	0.247	-0.046 *	0.0451 *	-0.1362 ***	0.1215 ***	-0.0432 *	-0.6778 ***			
8	Startup (< 5yrs)	0.057	0.231	-0.029	0.0359	-0.0148	0.0253	-0.0002	-0.2213 ***	0.3193 ***		
9	ln(work hours)	3.855	0.281	0.0134	-0.001	-0.0257	-0.0263	0.0097	-0.0812 ***	0.0731 ***	0.068 ***	
10	Percent of work hours devoted to inventing	52.816	30.562	0.1119 ***	0.0582 **	0.0849 ***	0.0075	0.009	0.02	0.0071	-0.0069	-0.0096

* p <.10, **p<.05, ***p<.01

Table 5.3 Correlation Between Pecuniary and Firm Motives by Firm Size

	Monetary Rewards			
	Overall	Large firm (>500)	Small firm (<100)	Startup (< 5yrs)
Firm Performance	0.0856**	0.0472	0.2184***	0.2636**

* p <.10, **p<.05, ***p<.01

5.2.2 Motives and Educational Background: Science and Engineering

Based on the Cosmopolitans-Local distinction (Gouldner, 1957b; 1958; Merton, 1957), we expected that educational backgrounds would moderate the relationship between motive and commercialization of the invention. In particular, we hypothesized that recognition motives would be positively associated with the commercialization of the invention for inventors with science backgrounds, and firm motives would be positively associated with commercialization of the invention for inventors with engineering backgrounds. Educational backgrounds were measured by disciplinary training and coded 1 for science backgrounds, otherwise 0.

Table 5.4 shows that inventors with science majors numbered 298 out of 711 samples after missing cases were removed. In model 1, we only included inventors with science backgrounds (N=298), and then, for the entire sample (N=711), we regressed the science variable only, without motives. The result showed that educational backgrounds, either science or engineering, were not significantly related to commercialization. In model 3, regression analysis was conducted for all samples with motives and science variables. The result reported a statistically stronger effect of the firm motive, and the task motive was also shown to positively influence commercialization. With interaction variables, we were not able to find any significant moderation effect of educational backgrounds on the relationship between motives and patent commercialization. In brief, results showed that we could not support our hypotheses E and F; we could not find a moderating effect of educational backgrounds.

Across model 4 through model 8, none of the interaction coefficients were significant, but this did not clearly indicate an interaction effect. As Norton et al. (2004) suggested, interaction terms (i.e. signs, magnitude and significance) varied by covariates. Based on our hypotheses, we created marginal effects and z-statistics of interaction terms using ***inteff*** command in STATA. As Figures from 5.1 to 5.3 show, none of the interaction effects were significant given that z-statistics were between $|z|<1.96$. We illustrated the interaction effect of each motive with science backgrounds as well as their z-statistics in Figure 5.1 to 5.3. What we found is that, for task and recognition motives, there was a positive interaction effect of science backgrounds, even though it was not statistically significant, and the marginal effect ranged close to 0. Figure 5.2 reports a negative interaction effect between firm motives and engineering backgrounds. Therefore, we cannot support hypothesis E and F.

To check robustness of the finding, we also ran the same analysis using the type of work (basic or applied research). It was operationalized as to whether inventors fit well into the work context based on socialization and motives. In the GT/RIETI Inventor Survey, we asked how much of the R&D effort leading to the focal patent was basic, applied design or technical service[8]. Out of 100%, respondents' median contribution to the basic research was 1%. Based on this, we created a dummy variable indicating basic research, 1 indicating inventions that had at least 1% of basic research effort; otherwise 0. The

---

[8] Exact questionnaire was the following: "At the time of the research leading to the focal patent, approximately what percentage of your R&D effort was…"

result is reported in Table 5.5, and we were not able to find significant interaction effect of the type of work, either.

Our findings are suggestive of the multidimensional conceptualization of cosmopolitans and locals. As opposed to distinguishing cosmopolitans and locals, some studies suggested that R&D employees' orientation toward the profession can be independent of their orientation toward the organization (Pelz, 1956). Also, it has been empirically found that highly-motivated scientists have features of both cosmopolitans and locals (Glaser, 1963). Friedlander (1971) examined 178 research scientists surveyed in six of the Navy's largest R&D labs, and reported greater multidimensional complexity in scientists' orientation. By comparing R&D scientists' orientation with their six disciplines (engineering, mathematics, physics, physiology, chemistry, and psychology), he found a significant difference among disciplines in professional orientation, but not in local orientation. In this regard, we suspect that our result could not support our hypotheses, because there are no pure-type cosmopolitans and locals.

Additionally, we suspect that we were not able to find the moderating effect of educational backgrounds because of a large PhD effect. In fact, about 72% of the inventors with science degrees held a PhD, while only 35% of the inventors with an engineering degree had a PhD. In future work, we would like to test the moderating effect by using PhD as a proxy for the cosmopolitan versus local argument.

In conclusion, we found a positive effect of task and firm motives on commercialization of the invention. However, we could not support our hypotheses that recognition motives were positively associated with the commercialization of the invention. Moreover, we could not find significant evidence to support a moderating effect of educational background in recognition motives, nor in firm motives on patent commercialization.

Table 5.4 Regression Results on Commercialization of the Invention, Interaction with Educational Backgrounds

	Dependent Variable: Commercial use of patented invention (Y/N)							
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	Science Only sample	All Sample	All Sample	Science*Task	Science_Firm	Science_Recognition	Science*Money	Interactions Included
Satisfaction of solving problem	0.254		0.225*	0.171	0.224*	0.221*	0.224*	0.174
	(0.187)		(0.117)	(0.151)	(0.117)	(0.118)	(0.117)	(0.150)
Generating value for the firm	0.263		0.226**	0.225**	0.200	0.227**	0.227**	0.200
	(0.166)		(0.101)	(0.101)	(0.131)	(0.101)	(0.102)	(0.130)
Recognition	0.066		0.029	0.025	0.030	-0.003	0.026	0.007
	(0.205)		(0.119)	(0.119)	(0.119)	(0.143)	(0.119)	(0.145)
Monetary Rewards	0.113		0.113	0.112	0.114	0.111	0.100	0.104
	(0.137)		(0.081)	(0.081)	(0.081)	(0.081)	(0.100)	(0.102)
Science background		0.026	0.081	-0.425	-0.186	0.075	-0.002	-0.708
		(0.204)	(0.209)	(1.051)	(0.903)	(0.210)	(0.403)	(1.529)
Science_Solving problem				0.116				0.105
				(0.237)				(0.241)
Science_Firm performance					0.064			0.066
					(0.213)			(0.215)
Science_Recognition						0.084		0.049
						(0.214)		(0.239)
Science_Monetary reward							0.036	0.022
							(0.152)	(0.169)
Technical Significance	0.402***	0.493***	0.480***	0.479***	0.481***	0.479***	0.480***	0.478***
	(0.136)	(0.089)	(0.092)	(0.092)	(0.092)	(0.092)	(0.092)	(0.092)
Size of Project	0.000	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
ln(work hours)	0.308	0.457	0.477	0.488	0.471	0.486	0.475	0.485
	(0.396)	(0.314)	(0.312)	(0.316)	(0.316)	(0.314)	(0.311)	(0.321)
Number of Inventors	-0.038	-0.002	-0.000	-0.000	-0.002	0.001	-0.001	-0.001
	(0.066)	(0.045)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)

Table 5.4 continued

Inventor's Tenure	-0.038	-0.012	0.000	-0.000	0.001	-0.000	0.000	0.000
	(0.067)	(0.034)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
(Inventor's Tenure)^2	0.001	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Master Degree	-0.060	-0.202	-0.151	-0.153	-0.153	-0.146	-0.152	-0.153
	(0.516)	(0.266)	(0.273)	(0.273)	(0.272)	(0.272)	(0.273)	(0.272)
PhD Degree	-0.723*	-0.489**	-0.500**	-0.494**	-0.503**	-0.498**	-0.500**	-0.497**
	(0.403)	(0.238)	(0.238)	(0.237)	(0.238)	(0.238)	(0.238)	(0.238)
SEEDS	-0.386	-0.595***	-0.604***	-0.608***	-0.602***	-0.604***	-0.604***	-0.605***
	(0.359)	(0.230)	(0.229)	(0.229)	(0.230)	(0.229)	(0.229)	(0.230)
NEWLINE	-0.138	-0.362*	-0.403*	-0.406*	-0.407*	-0.406*	-0.403*	-0.411*
	(0.337)	(0.218)	(0.222)	(0.223)	(0.222)	(0.222)	(0.222)	(0.222)
Number of USPC subclasses	0.041	-0.007	-0.007	-0.008	-0.007	-0.007	-0.007	-0.008
	(0.036)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Number of claims	-0.002	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003
	(0.009)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Large firm (>500)	-0.026	-0.577	-0.567	-0.575	-0.573	-0.573	-0.567	-0.584*
	(0.516)	(0.356)	(0.352)	(0.352)	(0.354)	(0.352)	(0.352)	(0.354)
Small firm (<100)	1.362*	0.800*	0.758	0.754	0.755	0.756	0.758	0.749
	(0.721)	(0.468)	(0.474)	(0.475)	(0.474)	(0.474)	(0.474)	(0.475)
Constant	-2.704	-0.939	-3.255*	-3.040*	-3.122*	-3.265*	-3.219*	-2.910*
	(2.350)	(1.524)	(1.677)	(1.687)	(1.728)	(1.681)	(1.666)	(1.739)
Technology Class	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Patent Filed Year	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	298	711	711	711	711	711	711	711
Log Likelihood	-204.17	-475.06	-475.06	-475.06	-475.06	-475.06	-475.06	-475.06
Wald Chi2	37.01	75.24	77.73	77.49	78.20	77.51	77.95	78.44
Pseudo R2	0.13	0.10	0.12	0.12	0.12	0.12	0.12	0.12

Robust standard errors in parentheses; Weighted by sampling weights

*** p<0.01, ** p<0.05, * p<0.1

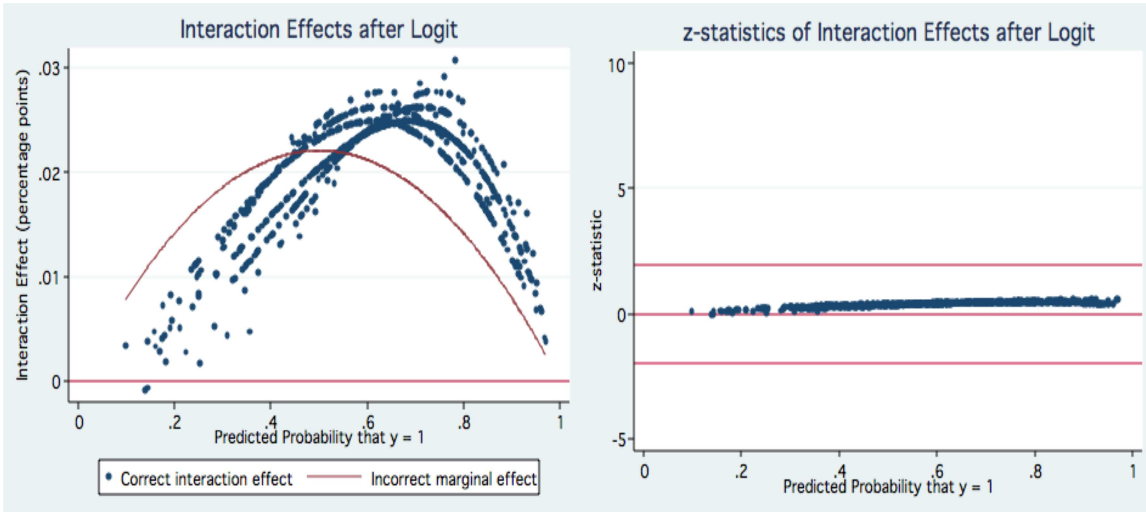


Figure 5.1 Interaction Effects of Task Motive and Science Background

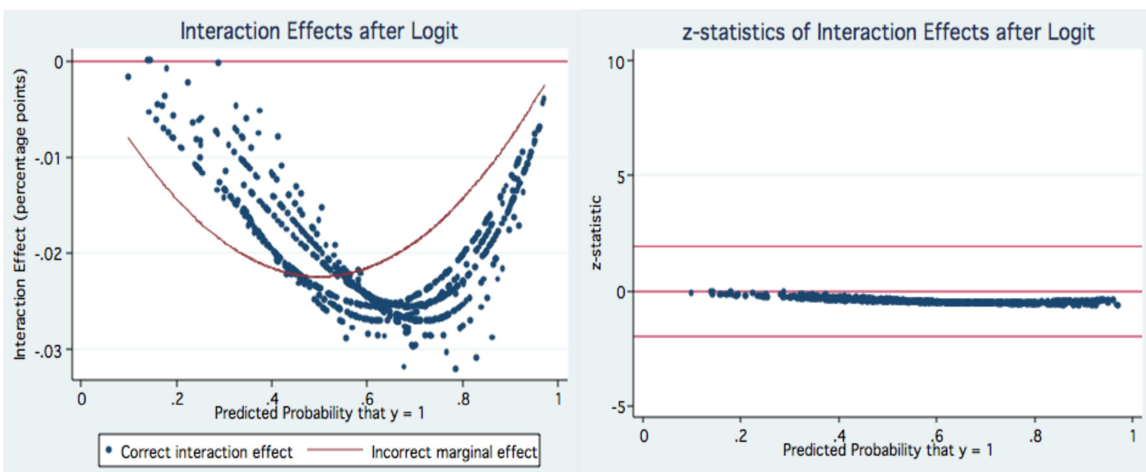


Figure 5.2 Interaction Effects of Firm Motive and Engineering Background

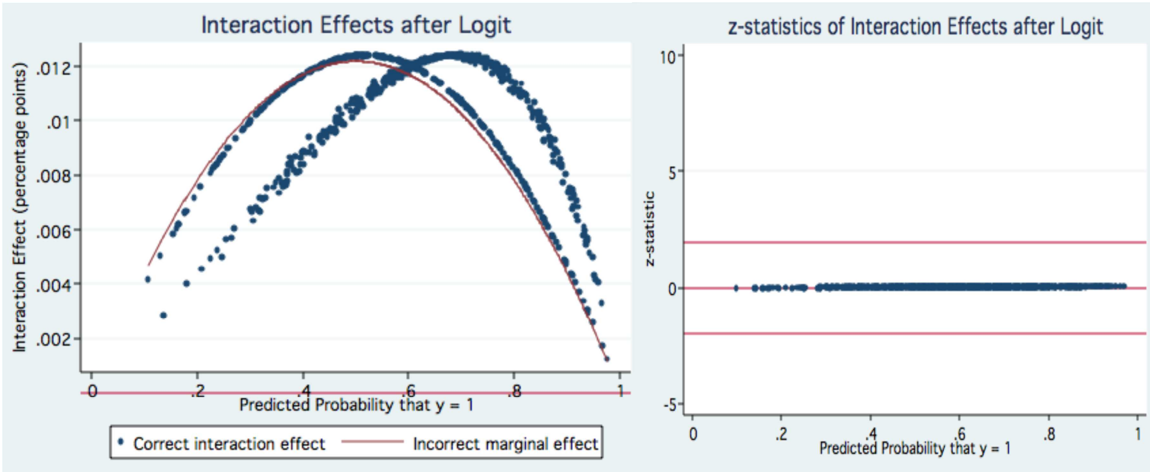


Figure 5.3 Interaction Effects of Recognition Motive and Science Background

Table 5.5 Regression Results on Commercialization of the Invention, Interaction with Basic Research

	Dependent Variable: Commercial use of patented invention (Y/N)						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	Basic Only sample	All Sample	Basic*Task	Basic_Firm	Basic_Recognition	Basic*Money	Interactions Included
Satisfaction of solving problem	0.308		0.188	0.230**	0.230**	0.225**	0.183
	(0.189)		(0.145)	(0.111)	(0.112)	(0.112)	(0.143)
Generating value for the firm	0.296*		0.205**	0.156	0.208**	0.211**	0.157
	(0.160)		(0.096)	(0.122)	(0.096)	(0.096)	(0.120)
Recognition	0.156		0.039	0.044	-0.018	0.041	0.022
	(0.211)		(0.114)	(0.113)	(0.133)	(0.115)	(0.135)
Monetary Rewards	0.227*		0.129*	0.132*	0.129*	0.053	0.058
	(0.135)		(0.075)	(0.075)	(0.074)	(0.090)	(0.092)
Basic		-0.273	-0.894	-0.898	-0.310*	-0.803**	-1.859
		(0.180)	(0.950)	(0.853)	(0.182)	(0.397)	(1.367)
Basic_Solving problem			0.138				0.109
			(0.216)				(0.225)
Basic_Firm performance				0.143			0.145
				(0.198)			(0.198)
Basic_Recognition					0.165		0.051
					(0.201)		(0.234)
Basic_Monetary reward						0.212	0.198
						(0.149)	(0.162)

Robust standard errors in parentheses; Weighted by sampling weights

*** p<0.01, ** p<0.05, * p<0.1

5.3 Robustness Check

In order to check the robustness of our findings, we conducted a new set of analysis for the sample that only consisted of solo inventors. Since we attributed one inventor's motive to the whole patent and its commercialization, we might introduce some measurement error. Therefore, we ran the following analysis shown in Table 5.6.

Unlike our main analysis, we did not find a positive effect of task, firm, or pecuniary motives on commercialization of the invention. However, the recognition motive, again, had a negative relationship on the commercialization of the patent. None of the effects were statistically significant, though task and pecuniary motives showed negative association with commercialization of the patent, which was contrary to the results of the entire sample, calling into question the main model. In the controls-only model, we found that the level of education and the type of project were not significant, unlike the results of the full sample (even though positive and negative signs were the same). Other than this, the technical significance of the patent and the size of the firm were reported to have the same effect on commercialization for the solo inventor sample. Therefore, we questioned if solo inventors just have different motives from non-solo inventors in terms of commercialization of the patent. The simple correlation analysis suggested that this could be the case. As illustrated in Table 5.7, the task motive showed a strong positive correlation with the commercialization of the patent for non-solo inventors, but turned out to have a negative association with the commercialization of the patent for solo inventors. Also, the strong positive association between the pecuniary motive and commercialization of the patent had become statistically insignificant. Therefore, we considered that the difference in the effects of motive is attributed to the difference between solo inventors and non-solo inventors, rather than to measurement error. In the next chapter, we will examine different motives that solo inventors and non-solo inventors (who are engaged in collaboration) have in more detail.

Table 5.6 Regression Results on Commercialization of the Invention, Solo Inventors Only

	Dependent Variable: Commercial use of patented invention (Y/N)					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Controls Only	Task Only	Firm Only	Recognition Only	Pecuniary Only	All Motives
Satisfaction of solving problem		-0.113				-0.101
		(0.253)				(0.257)
Generating value for the firm			0.112			0.132
			(0.192)			(0.194)
Recognition				-0.140		-0.150
				(0.217)		(0.246)
Monetary Rewards					-0.037	0.010
					(0.160)	(0.178)
Technical Significance	0.414**	0.427**	0.403**	0.432**	0.413**	0.434**
	(0.184)	(0.187)	(0.185)	(0.187)	(0.184)	(0.190)
Size of Project	0.013	0.013	0.013	0.012	0.013	0.012
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
ln(work hours)	0.700	0.673	0.728	0.592	0.665	0.613
	(0.746)	(0.753)	(0.735)	(0.769)	(0.758)	(0.764)
Inventor's Tenure	-0.022	-0.023	-0.016	-0.034	-0.025	-0.028
	(0.062)	(0.063)	(0.063)	(0.066)	(0.063)	(0.066)
$(\text{Inventor's Tenure})^2$	0.000	0.000	0.000	0.001	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
Master Degree	-0.749	-0.737	-0.705	-0.710	-0.740	-0.650
	(0.515)	(0.515)	(0.523)	(0.520)	(0.517)	(0.529)
PhD Degree	-0.789	-0.788	-0.756	-0.771	-0.792	-0.730
	(0.507)	(0.507)	(0.512)	(0.509)	(0.507)	(0.515)
SEEDS	-0.536	-0.536	-0.520	-0.512	-0.525	-0.495
	(0.465)	(0.466)	(0.468)	(0.468)	(0.469)	(0.472)
NEWLINE	-0.005	-0.013	-0.033	-0.022	0.016	-0.067
	(0.451)	(0.452)	(0.453)	(0.453)	(0.460)	(0.471)
Number of USPC subclasses	-0.021	-0.024	-0.024	-0.020	-0.019	-0.027
	(0.060)	(0.060)	(0.060)	(0.060)	(0.060)	(0.061)
Number of claims	-0.005	-0.005	-0.004	-0.006	-0.005	-0.004
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Large firm (>500)	-1.986*	-1.991*	-1.986*	-2.054*	-1.978*	-2.068*
	(1.130)	(1.129)	(1.129)	(1.137)	(1.132)	(1.138)
Small firm (<100)	-0.283	-0.305	-0.320	-0.454	-0.239	-0.544
	(1.241)	(1.240)	(1.239)	(1.267)	(1.257)	(1.311)
Constant	1.669	2.201	1.120	1.883	1.773	1.702
	(2.165)	(2.471)	(2.365)	(2.190)	(2.212)	(2.653)
Technology Class	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Patent Filed Year	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	188	188	188	188	188	188
Log Likelihood	-126.44	-126.44	-126.44	-126.44	-126.44	-126.44
Wald Chi2	52.38	52.58	52.72	52.80	52.43	53.39
Pseudo R2	0.21	0.21	0.21	0.21	0.21	0.21

Robust standard errors in parentheses; Weighted by sampling weights
*** p<0.01, ** p<0.05, * p<0.1

Table 5.7 Correlation Between Motives and Commercialization: Non-Solo versus Solo Inventors

		1	2	3	4	1	2	3	4
	Variables	Non-Solo Inventors				Solo Inventors			
1	Commercialization of patent								
2	Solving Problems	0.1017**				-0.0662			
3	Firm Performance	0.1063***	-0.0311			0.0678	0.0109		
4	Recognition	0.0485	0.2234***	-0.0233		-0.0632	0.1891***	0.0888	
5	Monetary Rewards	0.1379***	0.0542	0.0846**	0.2974***	0.0499	0.0308	0.0925	0.3012***

5.4 Conclusion and Discussion

In summation, we have observed positive effects of the task motive, the firm motive and the pecuniary motive on the commercialization of patents. Note, however, that the motive geared toward recognition had no significant effect on commercialization regardless of an inventor's educational background. Also, we have not found a moderation effect of educational background (science or engineering) on the relationship between motives and patent commercialization.

We understand that the larger portion of the variance of commercialization of invention is explained by non-individual factors such as organizational capability, technological distance, and geographical capacity (Jung, 2009; Huang, 2012). Even though we controlled for some of these (such as organization and project type) in our analysis, we acknowledge that it would not be enough to fully explain the path from individual motives to commercialization of the invention. Therefore, we wanted to see how individual inventor motives might contribute to commercialization besides their effect in producing valuable invention. There are several possible reasons why motive might affect commercialization, given the invention.

As to task motive, one possible explanation is that task-motivated inventors produce various work outputs that act as the seed of knowledge for commercialization of the focal patent. Because they enjoy solving the problem, it is likely that inventors with task motive are simultaneously engaged in multiple tasks, as long as the task is fun. In order to find the best solution, task-motivated inventors would seek out diverse ways for solving the problem, unlike inventors with other motives, and this trial and error could provide seed knowledge for task-motivated inventors. In turn, it is suspected to increase the odds of commercialization of the focal patent, and thus the net value of the invention. Thursby and Thursby (2011) have tested university faculty participation in licensing, and found that patent licensing activities is not diverting faculties' research profiles from basic to applied research. This result suggested that the financial incentive encourages faculty to conduct research more actively in general. Because of university faculties' orientation toward solving problems, university research can continue to explore both tracks of basic and applied research. Likewise, we propose that the odds of commercialization are higher for task-motivated inventors, since their curiosity-driven work portfolio provides the diverse knowledge background that can be utilized on other work outputs.

Another speculation was that inventors with a certain motive could be more engaged in the commercialization process. Some inventors could be more interested in commercializing their invention than others because their interest lies beyond the invention itself. In order to test this speculation, we looked at invention disclosures following Thursby and Thursby (2011). They used invention disclosure as a measure of faculty participation in licensing because it reflected faculty's willingness to engage in commercialization, and it was not influenced by the opinion of technology transfer office or firm's assessment of the commercial potential. Invention disclosure is under an individual's discretion in many cases. Even though a researcher comes up with a novel outcome, they might not take the trouble to disclose. Filing disclosure forms with the company may cause extra work for researchers, and it is not guaranteed whether a patent will be applied for, given that it has to go through another screening process by the firm's legal department. Therefore, invention disclosure can reflect inventors' willingness to commercialize their work output.

In the GT/RIETI Survey, we asked inventors approximately how many invention disclosures respondents had made in the last three years, so that we were able to run a correlation analysis. As reported in Table 5.2, we found that firm motive has a stronger positive correlation with the number of invention disclosures than inventors with other motives ($p < .01$). This may be because inventors with firm motives were more willing to engage in the extra work it would take to write up the significance of the work output. Moreover, frequently disclosing their work output illustrates that inventors with firm motives were more actively participating in their company's commercialization process. Since invention disclosures help the firm decide its potential, inventors with firm motives gave their organization more chances to explore an inventions' utility.

Moreover, inventors with firm motives were likely to devote their time and energy to ensure that knowledge was exchanged, understood, and integrated (Evans & Davis, 2005), and were more likely to deal with inconvenient work conditions created by others (Podsakoff et al., 2000). By understanding others and putting themselves in other people's shoes, inventors with firm motives were reported to increase their creativity since it broadens researchers' perspectives (Grant & Berry, 2011). In fact, we have found a strong positive correlation between firm motive and the sources of knowledge, both in the suggesting of and the completion of the project. This indicated that inventors with firm motive listen more to customers and suppliers, unlike task-motivated inventors, who were more likely to initiate as well as to complete the project without other's feedback.

With outside perspectives and inputs, firm-motivated inventors were more likely to create useful inventions than inventors with other motives.

Table 5.8 Correlation Between Motives and Sources of Knowledge

	Solving Puzzle	Firm Performance	Ribbon	Monetary Rewards
Idea suggested by customers	0.0091	0.1098***	0.0427	0.0407
Idea suggested by suppliers	0.0143	0.0974***	0.0979***	0.1095***
High_Idea suggested by customers	0.0171	0.1155***	0.0209	0.0563
high_Idea suggested by suppliers	0.0092	0.0817***	0.0216	0.0607
Idea completed by customers	0.0023	0.1186***	0.0888***	0.0919***
Idea completed by suppliers	0.0011	0.0820***	0.0931***	0.0877***
High_Idea completed by customers	0.0339	0.1159***	0.0903***	0.0761
high_Idea completed by suppliers	-0.0109	0.1090***	0.0283	0.0147

*** p<.01

In addition, we employed Sobel-Goodman tests to examine whether having an external source of knowledge served as a mediator influencing an independent variable to a dependent variable (Sobel, 1982). Among the sources of knowledge, we recoded a variable if the knowledge came from universities, government research organizations, customers, suppliers or competitors. After running Sobel-Goodman tests, we found that the mediation effect of external knowledge was somewhat substantive for firm, pecuniary and recognition motives. For firm and pecuniary motives, mediation effects were about 10% and 7%, respectively. As to recognition motive, a mediation effect was as large as 51%. Also, after adding the measure of external information, the coefficient of firm motive dropped, and the effect of firm motive became less significant. For the pecuniary motive, the coefficient also dropped, and the effect became insignificant. This result suggested that openness to others in conceiving and completing inventions mediated the relationship between motives (except the task motive) and commercialization of the inventions. This finding might provide some evidence supporting the assumption that inventors with firm motives are more likely to commercialize their inventions because they are more likely to integrate others' ideas into their inventions.

In this regard, we suggest that an inventor's input is still important in commercializing the patent. In particular, inventors with firm motive are recognized as a type of researcher who could be more actively involved in the company's commercializing effort. By being committed to the organization as well as prioritizing the goals of the firm, they are more willing to endure some of the inconveniences to their daily routine that pursuing innovation generates (Podsakoff et al., 2000).

This chapter examines individuals' motives as a way to understand innovation. In particular, we suggest that firm motive matters for industry researchers in R&D work settings. Our work extends the few empirical studies that argued the importance of task motive for industry engineers (Sauermann & Cohen, 2010; Stern, 2004). We claim that organizational commitment and intellectual challenge also matters for innovation.

CHAPTER 6. COLLABORATION AND MOTIVES

6.1 Introduction

Collaborative research has been increasing over the last several decades, and has come to be considered a key strategy in the pursuit of excellence in research as well as in innovation (Katz & Martin, 1997; Wuchty, Jones & Uzzi, 2007). Also, where research is conducted has been diversified in terms of arrangements and context. As of this writing, much of the nation's research is taking place in hybrid organizations that combine the characteristics of academia, industries, and government laboratories. Gibbons et al. (1994) asserted that, while knowledge production was once located primarily at scientific institutions (universities, government institutes and industrial research labs) and structured by scientific disciplines, it now resides in new, diverse locations, and that practices and principles are much more heterogeneous. The growth of collaboration and the assembling of multidisciplinary teams in research centers has been examined by co-authored papers (Etzkowitz & Kemelgor, 1999; Hicks & Katz, 1996). Also, using patent data, substantial empirical work on inter-organizational cooperation has been examined in the form of co-inventing, co-assignee and citation (Hagedoorn, 2003; Hicks, 1993; Hicks & Narin, 2001; Jaffe, Trajtenberg & Henderson, 1993). From archival data such as government documents and press releases, corporate collaborative work has been studied in the form of licensing, joint ventures, and formal R&D collaborations or consortia (Arora, Fosfuri & Gambardella, 2001; Sakakibara, 2002).

Researchers have argued that individuals are the prime movers of knowledge creation in an organization (Nonaka, 1994), and that collaboration among individuals who share their explicit and/or tacit knowledge could help knowledge creation at a collective level (Bartol & Srivastava, 2002; Quigley et al., 2007). Previous research stressed that communication among individuals is essential to exchange, combine and learn existing knowledge among co-workers in an effort to create organizational knowledge (Nahapiet & Ghoshal, 1998; Senge, 1990). As an important factor in technological progress, inventors need to utilize information and external opportunities in order to combine one's own capabilities and resources. In particular, given that inventing is increasingly considered to be a collaborative activity (Chesbrough, 2003), it has become important to understand the relationship between the individual inventor and collaborative activities. Biographical and clinical studies find that certain individual dispositions (i.e. independent, self-sufficient, and self-directed) are commonly used to describe successful scientists (Fox & Faver, 1984). This chapter addresses the relationship between the inventor and collaboration, and examines what types of individual motives affect collaborative activities.

We measured collaboration by co-inventing activities with those internal and external to the firm and by how many co-inventors were listed. As explained below, we set up the following hypotheses for the direct relationship between individual motives and collaborative patterns. Built upon previous literature suggesting that the experienced and the famous would gain a relatively small benefit by collaboration (Bozeman & Corley, 2004), we expected that recognition motive would play out differently on collaborative patterns based upon the inventor's experience. Also, due to high organizational commitment, we hypothesized that inventors with a high score on the firm motive would choose particular collaborative patterns in order to secure the firm's confidentiality.

Hypothesis I: Task motives are negatively associated with collaborative activity.

Hypothesis II: Pecuniary motives have no significant effect on collaborative activity.

Hypothesis III: Recognition motives are negatively associated with the instance of collaborative activity.

Hypothesis III-A: The relationship between recognition motives and collaborative activity is moderated by an inventor's tenure (interaction effect).

Hypothesis IV: Firm motives are positively associated with collaborative activity.

Hypothesis IV-A: For inventors with firm motive, the difference in collaborative activity is larger for internal collaboration than for external collaboration (interaction effect).

6.2 Regression Results

In this section, we present the analysis focusing on co-inventing pattern. We present the multinomial regression result in Table 6.1 in order to clearly illustrate the point of this chapter.[9] Then, the result of interaction effect between recognition motives and inventor experience is reported in Table 6.2. Focusing on the hypotheses III and III-A, Table 6.3 illustrates the regression result on any internal co-inventor.

Model 1 and 2 in Table 6.1 illustrate the base model regression that only includes control variables. The interesting findings of this research spoke to the effect of an advanced degree on collaboration. Contrary to the conventional belief, inventors with higher degrees were less likely to collaborate. Both master's and PhDs were less likely to participate in collaborative activities; this was especially prominent for external co-invention. We initially expected that, because of the academic training that advanced degree-holders received, inventors with higher degrees would work with outsiders like those from universities. However, compared to bachelor's degree inventors, masters and doctorate-educated inventors were significantly involved in non-heterogeneous collaboration (after controlling for the technical significance and the complexity of the technology, etc). We suspect this might be due to a perceived low payoff of collaboration held by advanced degree holders. Due to their sophisticated expertise, advanced degree inventors are more likely to consider that they can solve the problem by themselves than bachelor inventors. Increased level of expertise and confidence in their ability to solve the focal problem would prohibit inventors from participating in collaboration, particularly with external entities.

[9] We conducted the regression analysis on formal/informal collaborations as well as on the number of inventors listed in patent documents. Results were similar to that of the co-inventor, so they were not reported in this dissertation, but are available upon request.

In hypotheses I and II, we expected a rather simple direct effect of task and pecuniary motives. For the task motive, we anticipated a negative relationship with collaborative activities, and we hypothesized no effect between pecuniary motives and collaborative activities. We found that task motives had a positive effect on non-solo invention, as opposed to internal co-invention. Note that this effect was significant after controlling for the technical significance of the patent and the complexity of the technology. It indicates that task-oriented inventors would prefer to work by themselves even if how difficult and complex the invention is. Therefore, we can support our hypothesis I, which expected a decrease in collaborative activities. Since there is a preference for autonomy (Deci & Ryan, 1985), satisfaction is gained by problem-solving for task-motivated inventors, and as Cumming and Kisler (2007) suggested, collaboration may just not be fun for them.

Regarding pecuniary motives, we cannot support our hypothesis II. We expected no effect of this particular motive because inventors would weigh the positive and negative effects of collaboration, and they would cancel out each other in the decision whether or not to participate. However, we found a mixed effect of the pecuniary motive on collaboration. For the most part, pecuniary motive showed no significant effect on collaborative activities (i.e. the number of external co-inventors and internal co-inventors, both dummy and count dependent variables). However, we found a statistically positive relationship between pecuniary motives and dummy recoded external co-invention (See

Table 6.2, Model 1).[10] This was consistent with previous arguments, in that decisions on whether to participate in the collaborative activity were affected by monetary reward (Lawler, 1981; Osterloh & Frey, 2000). It signified that a company's monetary incentives awarded to participants of collaboration could encourage researchers to join collaborative activities.

In hypothesis III, we supposed that the recognition motive had a positive association with collaborative activities. Here, the recognition motive was measured by factor loading of four indicators: "career advance," "prestige/reputation," "recognition from co-workers," and "recognition from the field." Due to "endorsement" (Stuart, Hoang & Hybels, 1999) and "status leakage" (Podolny, 2005), we expected that recognition-motivated inventors would seek to expand their collaboration network. In addition, in hypothesis III-A, it was assumed that inventor's experience—measured by tenure after graduation—would moderate the relationship between recognition motives and collaborative activities. Based on the Matthew Effect (Merton, 1968; 1973a), we expected that less-experienced researchers were less likely to collaborate because they might worry about not receiving the credit they deserve. As for the more-experienced researchers, however, we expected that their established network of collaboration would expand based on the loop of positive feedback drawn by collaboration. We operationalized this moderation effect by

[10] In separate regression analysis on any external co-inventor, we found a positive association between pecuniary motive (using a regular non-dichotomized indicator) and any external co-inventor.

measuring the interaction effect between tenure and highly rated recognition motives.[11] We created dummy variables for each motive, coded 1 if the respondents reported a higher score, and 0 otherwise. Here, high score stands for either 4) Important, or 5) Very important. In the case of recognition factor loading, we recoded a high recognition variable, indicating 1 for the top 25%, otherwise 0. After examining survey categories in recognition variable, we found that all 4 variables' top 25% include scale 4) and 5), important and very important, respectively. Therefore, it seemed to be reasonable to choose upper quartile for illustrating high scores on the recognition motive. Then, we multiplied these dummy-coded motives with the years of inventor's tenure to test the interaction effects.

Looking at Table 6.1 (models 7, 8, 11 and 12), we cannot support hypothesis III, in that the recognition motive was not significantly associated with co-inventing activities. However, we found that recognition motives were positively associated with the number of external co-inventing, showing that this motive was associated positively with the size of external collaborative networks. Considering that the most valuable recognition comes out of external entities, this was not surprising. Inventors highly motivated by recognition were more likely to participate in collaborative activities as their tenure increased, particularly for external co-invention, which supported our hypothesis III-A (see Table 6.2). Our results reported that the interaction effect of this motive and tenure is

[11] We ran the same analysis substituting the tenure variable to the age variable, and the result was essentially the same. Therefore, we reported the analysis with the tenure variable, but the other analysis is available upon request.

statistically significant for model 4. In order to make sure the marginal effect distribution was statistically significant, we employed an interaction effect test by using ***inteff*** command in STATA. As portrayed in Figure 6.1, we found a positive marginal effect of interaction terms between recognition motive and tenure variable (even though it was close to 0). However, the z-statistic ranged from 0 to little over 1.96, so we cannot be confident in their statistical significance.

To summarize, we found partially supportive evidence for hypotheses III and III-A, in that the recognition motive was positively associated with the collaborative activity of external co-inventing. The fact that only external co-inventing appeared to have a significant relationship with recognition motives suggested that inventors' locus of interest leaned toward external entities rather than internal. As expected in hypothesis III-A, we found that inventors with high recognition motives were more likely to participate in co-invention as their experience increased, as did the size of their external collaborative network. Even though collaboration may not be that beneficial for an experienced inventor's productivity (Bozeman & Corley, 2004), inventors with an eye toward recognition have already established their own networks of collaboration, which they continue to maintain and expand (Hargadon & Sutton, 1997).

In hypotheses IV and IV-A, we suspected that firm motives would increase collaborative activities, and we hypothesized that the effect would be prominent in within firm co-inventing. Since our data could distinguish where collaboration took place (whether internally or externally), we could predict if organizationally committed inventors were particularly involved in collaboration in certain locations. Multinomial results in Table

6.1 show that firm-motivated inventors were significantly and negatively associated with external co-invention as opposed to internal co-invention (model 6). Also, Table 6.3 shows regression results on internal co-inventing, and we found that the firm motive was positively associated with the decision on whether to participate in internal co-inventing (See Table 6.3, models 3 & 6). The result turned out to have no significant relationship between firm motives and the number of internal/external co-inventors, and therefore, hypothesis IV could not be supported. However, we can support hypothesis IV-A in that the firm motive had a significant positive relationship with internal co-inventing.

We thought that inventors with firm motives were more likely to participate in collaboration because it creates a sense of helpfulness to inventors (Osterloh & Frey, 2000), and helps inventors to be attached to the community (Fox & Faver, 1984). Our results, however, suggested that the locus of interest seemed to lay especially in the firm where the inventor worked, where helping others in the same firm held a great deal of value. R&D employees with firm motives, for example, portrayed distinct characteristics of locals (Gouldner, 1957b; 1958; Merton, 1957) when it came to collaborative activities. Due to their local-like characteristics, inventors with firm motives established a trust and shared identity only with the same firm collaborators. Therefore, the transaction cost can be lowered within the firm by establishing explicit and implicit rules of coordination, and a shared identity and values (Dyer & Nobeoka, 2000).

In conclusion, we have found mixed results across hypotheses tested in this chapter. Task motives negatively influenced collaboration; thus, we can support hypothesis I. As for firm motives, we cannot support hypothesis IV as firm motives showed variance across all types of collaboration. However, this evidence more or less strengthened and supported hypothesis IV-A, in that organizationally committed inventors displayed local-like behaviors. Our results showed that inventors with firm motives, in particular, were more likely to internally co-invent as their motivation level increased. It appeared that firm motives were negatively associated with external co-inventions, compared to internal co-inventions (See models 6 and 12 in Table 6.1). Pecuniary motives showed mixed results; therefore, we cannot support hypothesis II. As for recognition motives, we cannot support hypothesis III, in that recognition motives were only positively associated with the number of external co-inventors, while other dependent variables on collaboration were not affected by this motive. However, we found evidence to support hypothesis III-A; inventors with high recognition motives reported participation in broader and larger networks of collaboration as their experience increased.

Table 6.1 Multinomial Regression Results on Co-Invention (Base: Any Internal Co-Inventor)

	Dependent Variable: Collaboartion Activities (base: Any Internal co-inventor)											
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
	Solo Inventor	Ext. Coinventor	Solo Inventor	Ext. Coinventor	Solo Inventor	Ext. Coinventor	Solo Inventor	Ext. Coinventor	Solo Inventor	Ext. Coinventor	Solo Inventor	Ext. Coinventor
Solving Problem			0.360***	-0.014							0.369***	-0.062
			(0.118)	(0.217)							(0.120)	(0.227)
Firm Performance					-0.076	-0.291*					-0.074	-0.313*
					(0.092)	(0.176)					(0.093)	(0.180)
Recognition							0.024	0.172			-0.044	0.193
							(0.100)	(0.219)			(0.110)	(0.238)
Monetary Rewards									0.004	0.043	0.015	0.026
									(0.070)	(0.146)	(0.076)	(0.154)
Technical Significance	-0.070	0.085	-0.087	0.087	-0.068	0.102	-0.072	0.069	-0.070	0.083	-0.082	0.088
	(0.084)	(0.177)	(0.085)	(0.177)	(0.084)	(0.179)	(0.085)	(0.179)	(0.084)	(0.178)	(0.086)	(0.181)
Inventor's Tenure	-0.004	-0.048	0.004	-0.048	-0.004	-0.046	-0.003	-0.041	-0.004	-0.047	0.003	-0.036
	(0.031)	(0.066)	(0.032)	(0.066)	(0.031)	(0.067)	(0.032)	(0.067)	(0.031)	(0.066)	(0.032)	(0.067)
(Inventor's Tenure)^2	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.000
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Number of Claims	0.001	-0.004	0.001	-0.004	0.001	-0.004	0.001	-0.004	0.001	-0.004	0.001	-0.003
	(0.005)	(0.011)	(0.005)	(0.011)	(0.005)	(0.011)	(0.005)	(0.011)	(0.005)	(0.011)	(0.005)	(0.011)
Number of USPC class	0.019	-0.146*	0.025	-0.147*	0.019	-0.145*	0.019	-0.150*	0.019	-0.147*	0.025	-0.151*
	(0.026)	(0.083)	(0.026)	(0.083)	(0.026)	(0.082)	(0.026)	(0.084)	(0.026)	(0.083)	(0.026)	(0.083)
Master Degree	0.100	-0.678	0.116	-0.671	0.088	-0.733	0.101	-0.671	0.100	-0.686	0.101	-0.724
	(0.247)	(0.485)	(0.249)	(0.485)	(0.248)	(0.488)	(0.247)	(0.485)	(0.247)	(0.486)	(0.250)	(0.490)
PhD Degree	0.122	-0.939**	0.145	-0.937**	0.112	-0.995**	0.117	-0.956**	0.123	-0.933**	0.148	-1.018**
	(0.222)	(0.457)	(0.224)	(0.457)	(0.223)	(0.459)	(0.223)	(0.458)	(0.222)	(0.457)	(0.227)	(0.461)
SEEDS	0.096	-0.237	0.062	-0.231	0.091	-0.243	0.095	-0.252	0.096	-0.242	0.056	-0.246
	(0.214)	(0.471)	(0.215)	(0.472)	(0.214)	(0.474)	(0.214)	(0.473)	(0.214)	(0.472)	(0.216)	(0.478)
NEWLINE	-0.198	-0.628	-0.226	-0.621	-0.194	-0.604	-0.198	-0.632	-0.199	-0.638	-0.224	-0.599
	(0.216)	(0.499)	(0.217)	(0.502)	(0.216)	(0.501)	(0.216)	(0.500)	(0.216)	(0.501)	(0.218)	(0.504)
Large firm (>500)	-0.183	-0.065	-0.133	-0.073	-0.167	-0.028	-0.180	-0.021	-0.184	-0.068	-0.125	-0.001
	(0.370)	(0.786)	(0.371)	(0.787)	(0.371)	(0.789)	(0.370)	(0.791)	(0.370)	(0.787)	(0.373)	(0.797)
Small firm (<100)	0.393	0.862	0.522	0.867	0.425	0.921	0.407	0.975	0.391	0.843	0.517	1.030
	(0.430)	(0.878)	(0.434)	(0.882)	(0.432)	(0.882)	(0.434)	(0.891)	(0.433)	(0.881)	(0.446)	(0.904)

Table 6.1 continued

Constant	-0.757	-17.097	-2.368**	-17.075	-0.424	-15.832	-0.756	-17.049	-0.768	-17.200	-2.124*	-14.534
	(1.056)	(0.000)	(1.197)	(0.000)	(1.133)	(0.000)	(1.057)	(0.000)	(1.072)	(0.000)	(1.284)	(0.000)
Technology Class	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Patent Filed Year	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	843	843	843	843	843	843	843	843	843	843	843	843
Log Likelihood	-571.56	-571.56	-571.56	-571.56	-571.56	-571.56	-571.56	-571.56	-571.56	-571.56	-571.56	-571.56
Wald Chi2	52.13	52.13	62.61	62.61	55.06	55.06	52.78	52.78	52.22	52.22	66.66	66.66
Pseudo R2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06

Robust standard errors in parentheses; Weighted by sampling weights

*** p<0.01, ** p<0.05, * p<0.1

Table 6.2 Regression Results on Co-Invention, Interaction Effects of Recognition Motives and Tenure

	Any External Co-inventor		Number of External Co-inventor		Any Internal Co-inventor		Number of Internal Co-inventor		Number of Inventor in Patent	
	Logit		ZIP		Logit		Poisson		Poisson	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
High_Recognition_Tenure		0.037		0.042**		0.004		0.0169		-0.00755
		(0.023)		(0.020)		(0.019)		(0.0183)		(0.00518)
High-Solving Problem	-0.454	-0.433	-0.624*	-0.641**	-0.326	-0.325	0.181	0.184	-0.0317	-0.0347
	(0.304)	(0.306)	(0.323)	(0.316)	(0.253)	(0.253)	(0.205)	(0.202)	(0.0556)	(0.0557)
High_Firm Performance	-0.328	-0.333	0.109	0.185	0.610***	0.609***	0.330	0.325	-0.0322	-0.0303
	(0.280)	(0.279)	(0.359)	(0.347)	(0.224)	(0.223)	(0.276)	(0.272)	(0.0679)	(0.0675)
High_Recognition	0.142	-0.574	0.564**	-0.239	-0.160	-0.227	-0.248	-0.523	-0.0917	0.0371
	(0.282)	(0.528)	(0.259)	(0.466)	(0.203)	(0.404)	(0.184)	(0.446)	(0.0616)	(0.116)
High_Monetary Reward	0.473*	0.468	0.361	0.296	0.186	0.184	-0.252	-0.256	-0.0105	-0.00748
	(0.284)	(0.287)	(0.331)	(0.322)	(0.214)	(0.214)	(0.244)	(0.243)	(0.0655)	(0.0652)
Inventor's Tenure	-0.032	-0.038	-0.002	-0.017	0.013	0.012	0.0175	0.0156	-0.00284	-0.00139
	(0.038)	(0.038)	(0.037)	(0.036)	(0.035)	(0.036)	(0.0175)	(0.0165)	(0.00922)	(0.00916)
(Inventor's Tenure)^2	0.001	0.001	0.000	0.000	-0.001	-0.001	-0.00110	-0.00116	-1.04e-05	7.75e-06
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000892)	(0.000924)	(0.000236)	(0.000235)
Base Model	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Technology Class	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Patent Filed Year	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	867	867	867	867	867	867	867	867	867	867
Log Likelihood	-295.84	-295.84	-393.01	-393.01	-520.43	-520.43	-3475	-3469	-1685	-1684
Wald Chi2	40.01	41.37	44.22	48.48	41.38	41.53	36.19	34.64	37.53	40.88
Pseudo R2	0.06	0.06			0.05	0.05				

Robust standard errors in parentheses; Weighted by sampling weights

*** p<0.01, ** p<0.05, * p<0.1

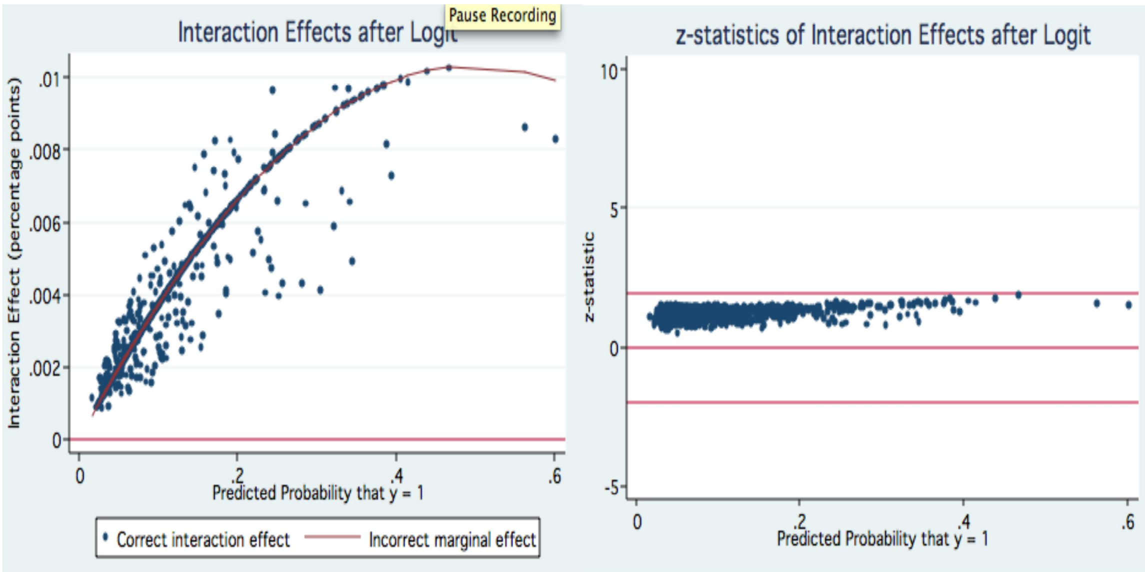


Figure 6.1 Interaction Effects of Recognition Motive and Tenure on Any External Co-inventor

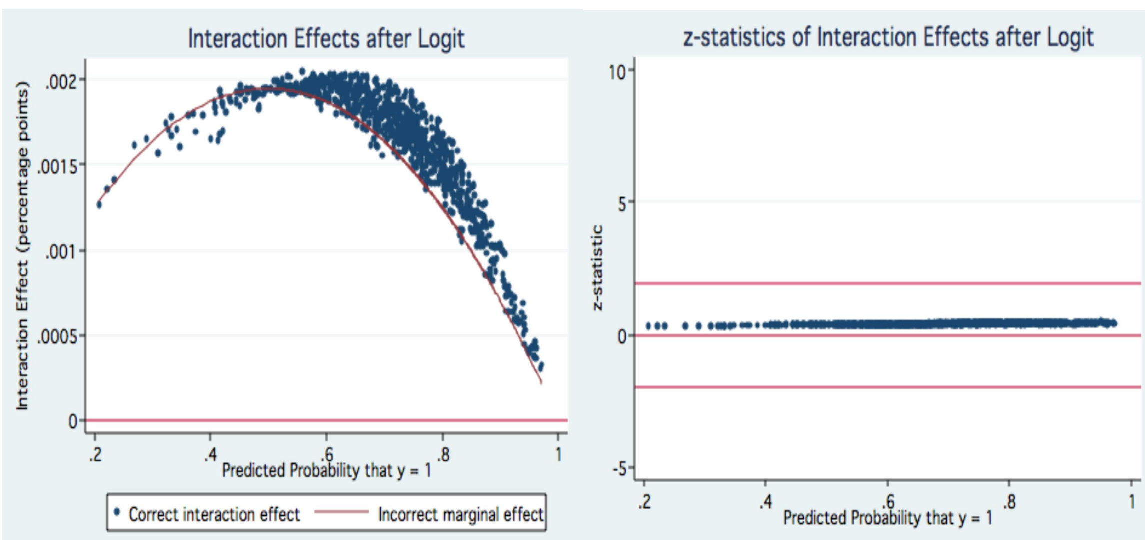


Figure 6.2 Interaction Effects of Recognition Motive and Tenure on Any Internal Co-inventor

Table 6.3 Regression Results on Any Internal Co-inventor

	Dependent Variable: Any Internal Co-Inventor (Y/N)					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Controls Only	Task Only	Firm Only	Recognition Only	Pecuniary Only	All Motives
Solving Problem		-0.381***				-0.393***
		(0.116)				(0.120)
Firm Performance			0.164*			0.165*
			(0.091)			(0.092)
Recognition				-0.006		0.050
				(0.098)		(0.109)
Monetary Rewards					0.008	-0.010
					(0.066)	(0.072)
Technical Significanc	0.070	0.088	0.063	0.070	0.069	0.078
	(0.085)	(0.085)	(0.085)	(0.086)	(0.085)	(0.085)
Inventor's Tenure	0.013	0.006	0.015	0.013	0.014	0.008
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
(Inventor's Tenure)^2	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of Claims	0.002	0.002	0.002	0.002	0.002	0.002
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Number of USPC clas	-0.001	-0.003	-0.001	-0.000	-0.001	-0.005
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Master Degree	-0.217	-0.232	-0.193	-0.217	-0.217	-0.205
	(0.254)	(0.257)	(0.253)	(0.254)	(0.254)	(0.256)
PhD Degree	-0.137	-0.148	-0.113	-0.135	-0.136	-0.137
	(0.226)	(0.226)	(0.226)	(0.227)	(0.227)	(0.230)
SEEDS	0.049	0.104	0.065	0.049	0.048	0.122
	(0.208)	(0.211)	(0.208)	(0.208)	(0.209)	(0.212)
NEWLINE	0.294	0.345	0.291	0.293	0.292	0.348
	(0.242)	(0.239)	(0.239)	(0.241)	(0.242)	(0.234)
Large firm (>500)	0.174	0.108	0.146	0.173	0.171	0.085
	(0.338)	(0.340)	(0.346)	(0.338)	(0.338)	(0.346)
Small firm (<100)	-0.358	-0.524	-0.421	-0.361	-0.364	-0.559
	(0.412)	(0.417)	(0.419)	(0.418)	(0.412)	(0.429)
Constant	0.428	2.107*	-0.296	0.427	0.410	1.473
	(1.079)	(1.163)	(1.144)	(1.079)	(1.100)	(1.237)
Technology Class	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Patent Filed Year	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	867	867	867	867	867	867
Log Likelihood	-520.43	-520.43	-520.43	-520.43	-520.43	-520.43
Wald Chi2	31.88	40.15	36.41	32.06	31.92	43.49
Pseudo R2	0.04	0.05	0.04	0.04	0.04	0.05

Robust standard errors in parentheses; Weighted by sampling weights
*** p<0.01, ** p<0.05, * p<0.1

6.3 Conclusion and Discussion

This study examined antecedents of collaboration, particularly focused on individual motives. We found that task motive suppressed collaborative activities, while pecuniary motive only positively affected whether or not there were external co-inventors (Lawler, 1981; Osterloh & Frey, 2000). Also, firm motives were found to increase chances of internal co-inventing. Regarding recognition motives, results suggested more senior people are more willing to participate, or more often invited to participate, or more able to handle participating, in larger collaborations.

With the increasing trend of collaboration (Chesbrough, 2003; Hicks & Narin, 2001; National Science Foundation, 2012) as well as nation-wide policies such as CRADA and ATP created to encourage collaboration, collaboration has gained more importance in the research on innovation. Through those policies, collaborative activities on the organizational level have increased (Walsh & Cohen, 2004). However, it is the individual who actually collaborates, so understanding the effect of individual differences on collaboration would be beneficial for successful collaborative activities. Previous literature has suggested that there are difficulties in motivating individuals to participate in collaborative networks and voluntarily share knowledge with other members (Wood & Gray, 1991). Since individuals and firms want to protect their competitive advantage (and often it is proprietary), they could be reluctant to participate in collaborative activities out of concerns about unwanted spillovers. Szulanski (1996) identified some of the impediments that individuals face in transferring knowledge. According to Szulanski (1996), individuals were reluctant to share knowledge because they feared losing a competitive advantage based on ownership of knowledge, and perceived that individuals would not be adequately rewarded for knowledge sharing. Individuals’ willingness to share their knowledge is difficult to change or manipulate (Lin, 2007), therefore, encouraging individuals to collaborate is one of the major challenges to increasing collaboration within and across organizations. In this regard, understanding what difference individual motives make in collaboration could complement organizational-level policies. Given that there are not many studies that quantitatively examined the collaboration pattern at the individual level, this study is expected to suggest managerial implications on the research of innovation. For example, assigning the right person is essential in order to synergize the effect of collaboration. The findings of this study demonstrated that it would be in the best interest of an inter-organizational collaborative effort to avoid putting together engineers who are focused on solving puzzles, and those who are organizationally-committed, despite the willingness of those more organizationally-committed engineers to participate in same-firm collaborative activities.

It should be also noted that incidences of external co-inventing were about 10% of the sample, indicating that there are few opportunities for industry inventors to actually work outside of their own firms. This was consistent with prior research suggesting that external co-invention in Japan was also about 13%, based on the Japanese version of the GT/RIETI Survey (Walsh & Nagaoka, 2009). In fact, this was not a surprising result considering that inventors with task motives and firm motives were reported to have negative associations with external co-invention. It suggests the importance of motivating industry researchers to participate in external collaboration, and making collaborative activities more fun for those inventors. In particular, given that collaboration among firms is a key ingredient for successful innovation (Chesbrough, 2003), and especially that vertical collaboration (with suppliers and customers) is shown to improve commercialization of the patents (Walsh & Nagaoka, 2009), our results call for attention to encouraging industry inventors to engage in external collaboration.

Issues around property rights should be considered when discussing collaboration. Because of issues around securing property rights, external collaboration (particularly in the form of co-inventing) was suspected to be restricted. Even though we understand the importance of external knowledge in coming up with the innovation (Cohen & Levinthal, 1990; Laursen & Salter, 2006; March, 1991; von Hippel, 1988), the practical problem of assigning proprietary rights can prohibit the actual implementation of the collaboration. Particularly, as opposed to other types of collaboration, results indicated that firm motivated inventors were more likely to collaborate only with researchers from the same firm. This could reflect that inventors with firm motives are less likely to work with entities outside of the firm due to considerations of secrecy or intellectual property rights, as this unwanted spillover could decrease the returns of the firm. Our data did not have information relating to the property rights or confidentiality issues in creating an invention, but we call for future research that answers the question of how to motivate firm-committed inventors to participate in external collaboration without sacrificing their positive work performance, both in terms of creativity and commercialization of the patent.

We observed that advanced degree-holding inventors were less likely to participate in external collaboration. Even if they had enough socialization from academia, the findings of this study indicated that communalism can be easily neglected when working in industry, with reference to both those inside and outside of their firm. In fact, some companies simultaneously restrict their engineers from publishing and presenting their research output, while encouraging conference attendance and journal subscription. This difference is even more striking when comparing company policies for filing a patent, in that they have rewarded engineers monetarily in order to promote patent applications. We may claim that industry R&D has provided strong incentives to un-socialize the academic scientific norm and exploited the scientific norm of "communalism." In order to cultivate the field of scientific research, reciprocity would be more sustainable in the long run. This leaves questions for future research regarding the balancing of property rights and communalism in industry R&D.

This study assumed that collaboration and knowledge sharing was the individual researcher's choice. However, this may not always be the case, since industrial collaboration can sometimes be unavoidable for the industry researchers. For example, some company strategies mandate employee participation in intra-firm collaboration. Moreover, when it comes to co-inventing, individuals' voluntary participation may be less likely given the proprietary nature of co-invention. Therefore, we must acknowledge that motives significantly affected collaboration even when it was a required activity.

CHAPTER 7. CONCLUSION AND POLICY IMPLICATIONS

7.1 Introduction

This research examined the individual antecedents of innovation performance and collaboration patterns. We proposed to expand the dimensions of motives in order to explain innovative performance in depth. Based on the novel dataset, the purpose of this was to answer questions regarding the relationship between motive and creativity with a focus on invention novelty, the effects of motive on invention commercialization and the interaction between an inventor's motives and educational background on invention commercialization, and last, how motive affected collaboration patterns. Innovative performances were examined with two perspectives: patent originality and patent usefulness. While there are ample studies examining the relationship between individual motive and creativity, this dissertation contributed to this literature by measuring creativity in terms of patented invention, and patent usefulness in terms of commercialization of the invention. As opposed to earlier studies examining creativity based on subjective measures such as supervisor's rating (see Grant & Berry, 2011), measuring creativity using bibliometric indicators tied to a patented invention is expected to increase the objectivity of the measure. Also, this dissertation examined the relationship between individual motives and patent commercialization based on survey data. It enabled this dissertation to distinguish if the patent had resulted in innovation, and examining individual motives and commercialized patents is relatively novel since earlier studies have relied on bibliometric data. Also, taking into account the importance of collaboration on the productivity of the research, this dissertation is expected to enhance our understanding as to how individual motives are associated with collaborative activities. In particular, investigating collaboration differences by the location of co-inventor is one of the advantages held by this dissertation.

While the collective actions of individuals form the resources and knowledge of organizations, there was a limited body of research that investigated knowledge recombination at the individual level in addition to the level of organizations (Felin & Hesterly, 2007; Rothaermel & Hess, 2007). The theoretical contribution of this dissertation is to fill that gap by demonstrating the effect of individual differences on innovative performance and knowledge creation as well as collaborative patterns. Empirically, this study contributes to the examination of innovation by focusing on invention and its commercialization, rather than by counting patents.

The unique dataset used in this study was based on a survey of 1,919 triadic patent inventors. It contained detailed information on the commercial uses of patents and collaboration patterns, as well as inventor characteristics. In addition, we created measures of the novelty of pairs of U.S. patent technology subclasses (USPC) based on the data of Lai et al. (2011) to measure the creativity of the patent. We have evidence that individual motives affected the production of new technological subclass pairs, commercialization of the patent, and collaborative activities.

In next section of this chapter, we summarize the results of each research question, give remarks on these findings, and propose policy implications and limitations of the research.

7.2 Summary of Key Findings

As summarized in Table 7.1, we first looked at the effect of motives on the novelty side of the invention, which was measured by the paired technology subclasses. This measure of recombinant technologies was employed as our operationalization of generative creativity (Fleming, Mingo & Chen, 2007). In Chapter 4, we found that recognition motives negatively influenced the creation of new combinations.

In Chapter 5, we investigated how motive influenced the commercialization of the invention, and if an inventor's educational background, measured by science or engineering major, moderated the effect of motives on the same dependent variable by looking at the usefulness of the invention. Since earlier studies addressed that scientists and engineers hold a different "basic orientation" (Merton, 1957) to external reference group or local community, respectively (Gouldner, 1957; 1958), we hypothesized that the effect of the motives would be moderated by an inventor's educational background. Industrial scientists were expected to be more innovative if they had a high recognition motive, whereas engineers were expected to be more innovative if they had a high firm motive. We observed a positive effect of the task, firm, and pecuniary motives on commercializing patents, but the recognition motive had no significant effect on commercialization. Also, we have not found any difference caused by inventors' educational backgrounds on the relationship between motives and patent commercialization.

As opposed to creating novel inventions, commercialization of the invention requires resources from the non-individual level. Hence, a larger portion of the commercialization of inventions has been explained by factors such as organizational capability, technological distance, and geographical capacity (Jung, 2009; Huang, 2012). Nonetheless, in order to explain why motives still matter for commercialization beyond the value of the invention, I assumed that inventors' willingness to engage in commercialization might be associated with particular motives. For example, our results indicated that inventors with firm motives were not only positively associated with the number of invention disclosures, but also more likely to employ external ideas both when initiating and completing the invention. This suggested that inventors with firm motives were more likely to exert additional effort for commercializing their work output, and to take external perspectives in producing their invention, which enhances applicability of the invention. This provides some evidence toward my assumption, in that particular motives might be more likely to be associated with the inventors' involvement in the commercialization process, and firm motive can be one example of those.

The last chapter investigated the effect of motive on collaboration. We examined the co-inventing pattern using co-inventor's locality (same-firm versus outside-of-the-firm) based on the GT/RIETI Survey. We found that task motive was negatively associated with collaborative activities, and the firm motive was particularly found to have positive effects on internal co-inventing.

Table 7.1 Summary of Key Findings

Dependent Variable	Hypothesis		Result
Creativity	HP3	Recognition ↓ New combinations	Negative
Commercialization	HP D	Firm ↑ Innovative performance	Positive
Collaboration	HP I	Task ↓ Collaborative activities	Negative
	HP IV-A	Firm ↑ Internal collaboration, rather than External collaboration	Positive

7.3 Discussions and Implications

7.3.1 Motives

This study suggested that inventors with firm motives could be the most productive and innovative researchers in industry R&D. They were positively associated with the creation of new combinations, commercialization of patents, and instances of collaboration with coworkers. These findings reflected the importance of organizational commitment for industry S&E professionals. Meyer and Allen (1991) defined effective organizational commitment as "emotional attachment to, identification with, and involvement in, the organization." Empirical studies testified that individuals with a higher level of organizational commitment performed better (Hunter & Thatcher, 2007; Morin et al., 2011; Vandenberghe, Bentein & Stinglhamber, 2004). Meta-analyses confirmed these results (Mathieu & Zajac, 1990; Meyer et al., 2002; Randall, Fedor & Longenecker, 1990; Riketta, 2002; Wright & Bonett, 2002), We suspect that organizationally-committed researchers feel attached to their firms, and thus do not consider themselves as "estranged labor" (Marx, 1932), which, in turn, positively affects their innovative performance. The sense of belonging garnered by, for example, a supervisor who listens and is attentive to employees' needs, can develop into commitment to the firm. Free from a sense of alienation, employees meet their need for security, and in this safe environment, are fully committed to their performances.

Inventors with firm motives are also likely to take others' perspectives, which, in turn, positively influences innovative performances. Mohrman, Gibson and Mohrman (2001) argued that employees were more likely to develop useful ideas when they took others' perspectives. Based on this, Grant and Berry (2011) reported the motive toward helping others brought useful creativity, since it broadened researchers' perspectives. We extended the boundary of others to the whole firm, and inferred that inventors with firm motives were more likely to generate useful creative ideas. Our data reported a strong positive correlation between firm motives and the sources of knowledge, both in suggesting the project and contributing to completion of the project (See Table 5.8), and we found some mediating effects of "openness to others" on the relationship between motive and commercialization of the invention. In other words, inventors with firm motive listened more to customers and suppliers, compared to task-motivated inventors, in both the initiation and the completion stages of the project, and this greater use of outside information partially explained their better commercialization performance. With perspectives and input from customers and suppliers, firm-motivated inventors were able to be more innovative than inventors with other motives.

Additionally, as reported in Table 5.2, we found that inventors with firm motives were more strongly positively associated with invention disclosure than inventors with other motives ($p < .01$). Given that invention disclosure to the firm requires initiative by employees (even if their contract mandates disclosure), we suspect that inventors with firm motives were more actively participating in the company's commercialization process. Considering that the ultimate goal of the firm is profit, this is another reason to value R&D researchers with firm motives.

Therefore, this dissertation suggests several managerial implications related to firms' need to develop policies that reduce employee's sense of estrangement. Perceived organizational support (Podsakoff et al., 2000), perceptions of procedural justice, and participation in the decision-making process (Konovsky, 2000) were reported as creating a work environment that induced commitment to the organization. Moreover, to build a sense of belonging, companies can launch programs focused on establishing strong mentorship and cohort-ship. For example, Samsung has created a strong sense of cohort with fellow employees who were hired in the same year through a summer-camp-like program. Also, increased mentorship in addition to desirable supervisory relationships would be a plus. Even though the system can generate "estranged labor," individually targeted policy can mitigate this effect.

Overall results suggested that recognition motives were not positively associated with innovative performances. It had a negative association with the creation of new combinations, and a non-significant association with the commercialization of the invention. Given that our sample was restricted to industry R&D employees, this finding indicated that Mertonian recognition is not as relevant for industry researchers as it is for university scientists. Merton's seminal work (1973) addressed that scientists were rewarded by a "priority-based reward system." Scientists produce specific types of knowledge, endowing credit for intellectual priority, establishing reputation, and opening the opportunity for involvement in prestigious institutions and access to resources for future research (Merton, 1973b). Dasgupta and David (1994) also made an important point as to how priority-based science works well in terms of development. They argued that a priority-based reward system expedited the development of science because scientists produced more knowledge within a system that reduced shirking by infusing an idea of "less work and less possibility of receiving rewards." As illustrated in Figure 3.1, however, industry inventors were more likely to consider that their job was to invent, as opposed to university inventors who cared more about their reputation in the field. Even though some have suggested that industry researchers crave recognition (Judge et al., 1997), our results implied that it may be worthwhile for R&D management to place stronger emphasis on other types of motives in order to generate a higher rate of innovative performances from industry researchers. For example, as opposed to providing publication opportunities, R&D managers are recommended to employ mechanisms that emphasize industry researchers' task, pecuniary and firm motives.

Note that we found a significantly negative association between recognition motive and new combinations. The result supported the assumption that there was risk associated with creativity, which could hamper the creativity of R&D employees. Considering that recognition-driven inventors are more likely to depend on other's approval, they can be more apprehensive about being different from others, and creating new ideas. In the firm level, creating work environments that protect R&D employees from encountering hard criticism might help encouraging recognition-driven inventors to come up with new ideas. Also, if inventors acknowledge that unusual inventions can be taken seriously under any circumstances in their work setting, recognition-driven R&D personnel would be less likely to worry about losing their reputation, which, in turn, might positively affect the creativeness of inventors with recognition motives.

7.3.2 New Combinations: Novelty and What?

Instead of focusing on how the idea was transferred and diffused, this research added evidence of individual effects on the process of idea generation (Damanpour, 1991; Fleming, 2001; Rogers, 1995). Even though we have found that firm motives positively affected the creation of new combinations of technology subclasses, we simultaneously found a significantly negative association with the recognition motive, and a positive association with variables such as bachelor's degree and a project aimed at enhancing existing lines of business. Since the positive association with these control variables was not expected with a measure of creativity, we questioned what the creativity measure could mean in addition to the novelty of the invention.

Based on our findings, we could argue that the creation of new combinations of technological subclasses is close to "exploitation" and minor contribution, rather than "exploration" and major contribution, such as technological breakthroughs (Mumford & Gustafson, 1988). Exploitation still signifies learning, improvement, and acquisition of new knowledge (Gupta, Smith & Shalley, 2006), but is based on an existing technological trajectory (Benner & Tushman, 2002; March, 1991). By putting together two never-combined technology subclasses, these inventions are based on existing technologies. Also, bridging one technology with another could be considered a refinement and extension, especially if the two technologies are close to each other;

therefore, it can be attributed as being close to exploitation. Taking this into account, it might not be surprising to find that inventors with firm motives and bachelor's degrees had a positive association with new combinations, in contrast to inventors with recognition motives.

In this regard, there is an avenue for future research. I propose to measure the technological distance of new combinations, and to describe as to where the new combination is located in the continuum of creativity. Our measure of new combinations allows us to distinguish the extent to which combinations are technically close to each other. If each technological subclass in the new combination belongs to the same technology class, it is considered incremental creativity. Contrarily, the new combination will be considered as a technological breakthrough if each of the subclasses belongs to two different technology classes. This process will expand our understanding as to what new combinations really mean, and the relationship between individual motive and degree of creativity.

7.3.3 Collaboration at the Individual Level

With the extra help of national policies such as CRADA and ATP, collaboration is an increasing trend (Chesbrough, 2003; Hicks & Narin, 2001; National Science Foundation, 2012). Through those policies, collaborative activities on an organizational-level have increased (Walsh & Cohen, 2004). However, collaboration is conducted at the individual level, and it has been reported that knowledge-sharing behavior is hard to change and manipulate (Lin, 2007). Previous literature has suggested that there were difficulties in motivating individuals to participate in collaborative networks and voluntarily share knowledge with other members (Wood & Gray, 1991). Szulanski (1996) also mentioned that individuals were reluctant to share knowledge because they could fear the loss of competitive advantage based on ownership of the knowledge, and perceived that individuals who shared their knowledge were not adequately rewarded. Therefore, understanding what individual differences make in collaboration could complement organizational-level policies in order to enhance the instances and effect of collaboration.

Our results showed that inventors with task motives were less likely to participate in collaborative activities due to their innate preference toward autonomy, and because their satisfaction is derived from solving problems. Monetary rewards may persuade researchers with pecuniary motives to participate in external co-invention, but do not necessarily expand the size of their collaborative networks. The possibility of sharing rewards with collaborators could inhibit pecuniary-motivated inventors from increasing the size of collaboration. Also, we found that the firm motive only increased internal co-inventing. As for the recognition motive, the results presented a positive association with the size of the external collaborative network.

Given that collaboration among firms is a key ingredient for successful innovation (Chesbrough, 2003), and especially since vertical collaboration (with suppliers and customers) has been shown to improve commercialization of the patents (Walsh & Nagaoka, 2009), our results call for appropriate policies that will help to stimulate industry inventors to engage in external collaboration. Firm practices that are geared toward making collaboration fun or enjoyable for task and firm-motivated employees should be implemented, as well as policies that will help employers determine how to best match inventors with different motives to an external collaborative project for the maximum obtainable benefit for the endeavor. Implications of these policies can be seen in these examples: researchers with task motives could be assigned certain tasks exclusively for them, even though it may be a part of a larger collaborative work, making those researchers more likely to enjoy the work since the “task” is solely theirs to solve; and for inventors with a strong attachment to the firm, the company could initiate the collaborative project by assuring them of the benefit the project could bring to the firm. As for external collaborations, an organization would do well to advise inventors in advance about the property rights and/or property assigning issues that could otherwise be a barrier to participation.

Taking into account the previous literature claiming the benefit of collaboration on research output and innovation (Jones, 2009; Chesbrough, 2003), there is an opportunity for future research. We can connect the three dependent variables employed in this research to see if collaboration mediates the relationship between inventor motives and innovative performances. Given that we measured innovative performances by patent originality and patent usefulness, this future research is expected to enhance our understanding as to how collaboration differently influences those variables, and the extent to which the impact of motives on performance is the result of how motives affect collaboration. Moreover, it can provide additional managerial implications as to the extent to which motives need to be emphasized in the industry R&D setting. For example, we observed that task motives were not significantly associated with collaboration activities, yet were positively associated with the creation of new combinations as well as the commercialization of the invention. Considering the importance of external inputs in innovation, this future research could contribute to further understandings as to how the link between task-motivated inventors and innovative performances can be enhanced with external collaboration.

7.4 Research Limitations

This study had several limitations. Primary among them was that the variance of the task motive was small. As described in Chapter 3, the mean score of task motives was 4.4, with standard deviation 0.84. It had the smallest standard deviation among all motive categories.[12] In Figure 3.2, we have also shown that 75% of the sample rated that satisfaction from solving a puzzle or completing a task was either important or very important. In other words, the task motive was considered essential for industry R&D researchers. Therefore, there was not much variance to explain task motives, even though it was one of the most significantly discussed motives in this study. In this regard, we would like to investigate what is so special about the task motive. It is the characteristic that distinguishes laymen from scientists and engineers (General Social Survey, 2001), and even with that small variance, in this research task motive evidenced positive effect on the creation of new combinations and the commercialization of the invention. A field study can be proposed in order to closely examine the task-motivated inventors in industry and the effect on innovative performances.

[12] It was consistent with Sauermann and Cohen (2010), in that intellectual challenge had the highest mean score and the smallest standard deviation among all categories of the motives.

Moreover, we would like to acknowledge that collaboration among industrial researchers is not 100% the individual's choice. Collaboration in industry can be mandatory to a certain extent, and moreover, when it comes to co-inventing, an individual's voluntary participations may be less likely given the proprietary nature of the co-invention. Therefore, we were cautious in interpreting our results in a way that assumed the individual researcher could choose their participation in collaborative project, regardless of situation.

Another limitation was related to endogeneity. First, given the nature of the data, our key variables reflected constructs at the time of the survey. Especially considering that individual motives can change upon situational factors, i.e. individuals recently being monetarily rewarded, we should examined if individual motives were systematically affected by their past performances. As mentioned in the literature review section, we assumed that individual motives were more "trait-like," which implies stable characteristics, but that assumption may not hold and it would be better if we could control for this explicitly.

Again, note that our sample was selected on triadic patents (filed in Japan and European Patent office and granted in the U.S. Patent Office), connoting technically significant inventions with higher probability of global commercialization. Therefore, the results can be skewed to the high performers, and we employed Heckman selection by including the residual in the first-stage OLS regression (Wooldridge, 2001) to investigate this possibility. Using variables like being married or having children at the moment of developing the focal patent, we tested the first-stage regression. The results on commercialization of the patent, for example, did not show significant effects of those variables on the residuals, and no significant associations between the first and second stage models. Therefore, we need to further investigate as to which instrument variables can appropriately address this possibility.

Additionally, there is a potential issue relating to the selections at the individual and firm levels. We considered that individuals' employment in a particular firm size was not the result of a random assignment, but a self-selection by the individual and/or selection by the organization. Accordingly, our results may be biased to the extent that selection into firm size (e.g., those that are more productive) depends on individual motives. We examined this possibility by exploiting measures of motives to see if they were associated with their employment in a particular firm type. Our results of multinomial logit regression on firm size suggested that pecuniary motives were positively associated with small firm as opposed to large firm, and task and recognition motives were negatively associated with small firm as opposed to large firm. However, in order to fully address the possible selection biases, we need to find proper instrument variables that only affect selection into the firm, but do not influence our dependent variables.

In interpreting the results on innovative performance, it should be also noted that firm size may determine our performance regressions. For example, our results indicated that small firms had a positive association with the creation of new combinations, but it is possible that having new combinations could have resulted in those firms appearing in our sample. We expect that this selection bias differs from industries where patents matter the most in creation of new companies, such as Pharmaceuticals (Cohen et al., 2000). Therefore, we could have enhanced our robustness by running regressions using industry subsamples, for example, between Pharmaceuticals and Computer System Design. Our sample, however, had only 31 cases of Computer System Design (NAICS 5415); therefore, we instead employed the regression analysis without start-up companies (less than 5 years old) since they could be more or less influenced by the focal patent in the analysis. The results indicated that the positive effect between small firms and the creation of new combinations disappeared, but the result on the motives remained the same.

7.5 Policy Implications

The patent system has long served as an important policy instrument for stimulating innovation. Based on this fundamental mechanism of endowing exclusive rights in exchange for disclosing inventions, patents are expected to be commercialized in order to actually fulfill the purpose of innovation. Nonetheless, there are many unused patents available, which is one reason for recent discussion on “sleeping patents” (Arya & Mittendorf, 2004; Jung, 2009). Even though we acknowledge that some patents are strategically unused (see Jung, 2009), many countries around the world have debated policies to stimulate commercialization of patented inventions. The Bayh-Dole Act is one such policy designed to increase use of patents from Federally-funded research. The U.K. recently (April, 2013) introduced a policy called “the Patent Box,” which allowed companies to apply a lower rate of corporation tax on profits from exploiting patented inventions.[13]

In this regard, this research contributes to our understanding as to how individuals' motives might enhance the uses of invention. By examining individuals' motives for generating more creative patents and generating more commercialization of inventions, we have expanded our understanding on what motives should be more emphasized for industry researchers, and this should be taken into consideration when formulating policies.

[13] http://www.hmrc.gov.uk/ct/forms-rates/claims/patent-box.htm

REFERENCES

Adler, P.S., S. Kwon, and C. Heckscher. 2008. "Perspective-Professional Work: The Emergence of Collaborative Community." *Organization Science* 19(2):359-76.

Afuah, Alan. 2003. *Innovation Management: Strategies, Implementation and Profits*: Oxford University Press.

Allen, R. C. 1984. "Collective Invention." *Journal of Economic Behavior and Organization* 4:1-24.

Allen, T. J. 1977. *Managing the Flow of Technology*. Cambridge, MA: MIT Press.

Allison, P. D. 1980. *Processes of Stratification in Science*. New York: Arno Press.

Amabile, T. 1983. *The Social Psychology of Creativity*. New York: Springer-Verlag.

—. 1993. "Motivational Synergy: Toward New Conceptualizations of Intrinsic And Extrinsic Motivation In The Workplace." *Human Resource Management Review* 3:185-201.

Amabile, T. M. 1985. "Motivation and Creativity -Effects of Motivation Orientation on Creative Writers." *Journal of Personality and Social Psychology* 48(2):393-99.

—. 1988. "A Model of Creativity and Innovation in Organizations." *Research in Organizational Behavior* 10:123-67.

—. 1996. *Creativity in Context*. Boulder, Co: Westview.

Amabile, T. M., S. G. Barsade, J. S. Mueller, and B. M. Staw. 2005. "Affect and Creativity at Work." *Administrative Science Quarterly* 50:367-403.

Amabile, T. M., R. Conti, H. Coon, J. Lazenby, and M. Herron. 1996. "Assessing the Work Environment for Creativity." *The Academy of Management Journal* 39(5):1154-84.

Amabile, T. M., B. A. Hennessey, and B. S. Grossman. 1986. "Social Influences on Creativity - The Effects of Contracted-for Reward." *Journal of Personality and Social Psychology* 50(1):14-23.

Amabile, T. M., K. G. Hill, B. A. Hennessey, and E. M. Tighe. 1994. "The Work Preference Inventory - Assessing Intrinsic And Extrinsic Motivational Orientations." *Journal of Personality and Social Psychology* 66(5):950-67.

Ancona, D. G., and D. F Caldwell. 1992. "Demography and Design: Perdictors of New Product Team Performance." *Organization Science* 3(3):321-41.

Andrews, F. M. 1979. *Scientific Productivity*. Cambridge, England: Cambridge University Press.

Andrews, F. M., and G. F. Farris. 1967. "Supervisory Practices and Innovation in Scientific Teams." *Personnel Psychology* 20:497-575.

Aoshima, Yaichi, and Tatsuya Kubota. 2011. "An Influence of Organizational Positioning of R&D Activity on Innovation Process: A Comparative Analysis of ArF Resist Materials Development." in *IIR Working Paper*: Institute of Innovation Research, Hitotsubashi University.

Arora, A., A. Fosfuri, and A. Gambardella. 2001. *Market for Technology*. Cambridge: MIT Press.

Arrow, K. 1962. "Economic welfare and the allocation of resources for invention." Pp. 609-26 in *The Rate and Direction of Inventive Activity*, edited by Universities-National Bureau Committee for Economic Research. Cambridge, MA: Harvard Business School Press.

Arya, A., and B. Mittendorf. 2004. "Purchasing sleeping patents to curtail budget padding." *Economics Letters* 82(2):221-26.

Ashforth, B. E., S. H. Harrison, and K. G Corley. 2008. "Identification in Organizations: An Examination of Four Fundamental Questions." *Journal of Management* 34(3):325-74.

Ashforth, B. E., and F. A. Mael. 1989. "Social Identity Theory and the Organization." *Academy of Management Review* 14:20-39.

Barron, F., and D. M. Harrington. 1981. "Creativity, Intelligence, and Personality." *Annual Review of Psychology* 32:439-76.

Bartol, K, and A. Srivastava. 2002. "Encouraging Knowledge Sharing: The Role of Organizational Reward Systems." *Journal of Leadership and Organiztional Studies* 19(1):64-76.

Beaver, D., and R. Rosen. 1978. "Studies in Scientific Collaboration: Part I - The Professional Origins of Scientific Co-authorship." *Scientometrics* 1(1):65-84.

—. 1979. "Studies in Scientific Collaboration: Part II - Scientific Co-authorship, Research Productivity and Visibility in the French Scientific Elite, 1799-1830." *Scientometrics* 1(3):133-49.

Bendix, R. 1974. *Work and Authority in Industry*. Berkeley: University of California Press.

Benner, M. J., and M. L. Tushman. 2002. "Process management and technological innovation: A longitudinal study of the photography and paint industries." *Administrative Science Quarterly* 47:676-706.

Bikard, Michael, and Fiona Murray. 2010. "Is Collaboration Creative? Examining the Organization of Knowledge Work." in *Annual Meeting of Academy of Management*. Montreal, Canada.

Bock, G. W., R. W. Zmud, and Y. G. Kim. 2005. "Behavioral Inention Formation in Knowledge Sharing: Examining the Roles of Extrinsic Motivators, Social-Psychological Forces, and Organizational Climates." *MIS Quarterly* 29(1):87-111.

Bozeman, B., and E. Corley. 2004. "Scientists' Collaboration Strategies: Implications for Scientific and Technical Human Capital." *Research Policy* 33(4):599-616.

Branstetter, L., and M. Sakakibara. 1998. "Japanese research consortia: A microeconometric analysis of industrial policy." *Journal of Industrial Economics* 46(2):207-33.

Burt, R. 2004. "Structural Holes and Good Ideas." *American Journal of Sociology* 110(2):349-99.

Caloghirou, Y., I. Kastelli, and A. Tsakanikas. 2004. "Internal Capabilities and External Knowledge Sources: Complements or Substitutes for Innovative Performance?" *Technovation* 24(1):29-39.

Camerer, C. F., and R. Hogarth. 1999. "The Effects of Financial Incentives in Economics Experiments: A Review and Capital-Labor-Production Framework." *Journal of Risk and Uncertainty* 19:7-42.

Cantwell, John. 2005. "Innovation and Competitiveness." Pp. 543-67 in *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery, and Richard R. Nelson. Oxford, UK: Oxford University Press.

Chen, C. C., C. M. Ford, and G. F. Farris. 1999. "Do Rewards Benefit the Organization? The Effects of Reward Types and the Perception of Diverse R&D Professionals." *IEEE Transactions on Engineering Management* 46(1):47-55.

Chesbrough, Henry. 2003. *Open Innovation*. Boston: Harvard Business School.

Cohen, W. M., and Steven Klepper. 1996. "Firm Size and the Nature of Innovation within Industries: The Case of Process and Product R&D." *The Review of Economics and Statistics* 78(2):232-43.

Cohen, W. M., and D. A. Levinthal. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35:128-52.

Cohen, W. M., R. R. Nelson, and J. P. Walsh. 2002. "Links and Impacts: The Influence of Public Research on Industrial R&D." *Management Science* 48:1-23.

Cohen, W. M., and H. Sauermann. 2007. "Schumpeter's Prophecy and Individual Incentives as a Driver of Innovation." Pp. 73-104 in *Perspectives on Innovation*, edited by F. Malerba and S. Brusoni: Cambridge University Press.

Cohen, W.M., and J.P. Walsh. 2008. "Real impediments to biomedical research." *Innovation Policy and the Economy* 8:1-30.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh. 2000a. "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not)." in *NBER Working Paper #7552*.

—. 2000b. "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)." in *NBER Working Paper*: National Bureau of Economic Research.

Cole, J. R., and S. Cole. 1973. *Social Stratification in Science*. Chicago: University of Chicago Press.

Cottrell, A. H. 1962. "Scientists: Solo or Concerted?" Pp. 388-93 in *The Sociology of Science*, edited by B. Barber and W. Hirsch. New York: Free Press.

Csikszentmihalyi, M. 1999. *Creativity*. New York: Harper Collins.

Cummings, Jonathon N., and Sara Kiesler. 2007. "Coordination Costs and Project Outcomes in Multi-University Collaborations." *Research Policy* 36(10):1620-34.

Damanpour, Fariborz. 1991. "Orgaizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators." *Academy of Management Journal* 34(3):555-90.

Dasgupta, P., and P. A. David. 1994. "Toward A New Economics Of Science." *Research Policy* 23(5):487-521.

Deci, E. L., and R. Flaste. 1995. *Why We Do What We Do: The Dynamics of Personal Autonomy*. New York: Putnam.

Deci, E. L., R. Koestner, and R. M. Ryan. 1999. "A Meta-Analytic Review of Experiments Examining the Effect of Extrinsic Rewards on Intrinsic Motivation." *Psychological Bulletin* 125(6):627-68.

Deci, E. L., and R. M. Ryan. 1985. "The General Causality Orientations Scale: Self-determination in Personality." *Journal of Research in Personality* 19:109-34.

Dewett, Todd. 2007. "Linking intrinsic motivation, risk taking, and employee creativity in an R&D environment." *R & D Management* 37(3):197-208.

Dillman, Don A. 1978. *Mail and Telephone Surveys*. New York: John Wiley & Sons.

DiMaggio, P. 2003. *The Twenty-Firsty-Century Firm: Changing Economic Organization in International Perspective*. Princeton: Princeton Univ Press.

Dougherty, D. 1992. "Interpretive Barriers to Successful Product Innovation in Large Firms." *Organization Science* 3(2):179-202.

Dyer, J. H., and K. Nobeoka. 2000. "Creating and Managing a High-Performance Knowledge-Sharing Network: The Toyota Case." *Strategic Management Journal* 21(3):345-67.

Dyer, J. H., and H. Singh. 1988. "The Relational View: Cooperative Strategy and Sources of Interorgainzational Competitive Advantage." *Academy of Management Review* 23(4):660-79.

Eisenberger, R., and J. Cameron. 1996. "Detrimental Effects of Reward: Reality or Myth?" *American Psychologist* 51:1153-66.

Elsbach, K. D., and A. Hargadon. 2006. "Enhancing Creativity through "Mindelss" Work: A Framework of Workday Design." *Organization Science* 17(4):470-83.

Etzkowitz, H., and Carol Kemelgor. 1999. "Research Centers: The Collectivisation of Academic Science." *Minerva* 36(4).

Evans, W. R., and W. D. Davis. 2005. "High-performance work systems and organizational performance: The mediating role of internal social structure." *Journal of Management* 31(5):758-75.

Fagerberg, J., D. C. Mowery, and R. R. Nelson. 2004. *The Oxford Handbook of Innovation*. Oxford, UK: Oxford University Press.

Farr, J. L., and C. M. Ford. 1990. "Individual Innovation." Pp. 63-80 in *Innovation and Creativity at Work*, edited by M. A. West and J. L. Farr. Chichester, England: Wiley.

Felin, Teppo, and William S. Hesterly. 2007. "The knowledge-based view, nested heterogeneity, and new value creation: Philosophical considerations on the locus of knowledge." *Academy of Management Review* 32(1):195-218.

Fenwich, R., and J. Olson. 1986. "Support for Worker Participation: Attitudes Among Union and Non-Union Workers." *American Sociological Review* 51(4):505-22.

Finholt, Thomas A. 2002. "Collaboratories." *Annual Review of Information Science and Technology* 36:73-107.

Fleming, Lee. 2001. "Recombinant Uncertainty in Technological Search." *Management Science* 47:117-32.

Fleming, Lee, Santiago Mingo, and David Chen. 2007. "Collaborative Brokerage, Generative Creativity, and Creative Success." *Administrative Science Quarterly* 52:443-75.

Fox, Mary Frank, and Catherine A. Faver. 1984. "Independence and Cooperation in Research." *Journal of Higher Education* 55(3 (May-Jun., 1984)):347-59.

Fredrickson, B. L. 1998. "What Good are Positive Emotions?" *Review of General Psychology* 3:300-19.

Frey, B. S., and R. Jegen. 2001. "Motivation Crowding Theory." *Journal of Economic Surveys* 15(5):589-611.

Friedlander, F. 1971. "Performance and Orientation Structures of Research Scientists." *Organizational Behavior and Human Performance* 6:169-83.

Gagne, M., E. Chemolli, J. Forest, and R. Koestner. 2008. "A Temporal Analysis of the Relation Between Organisational Commitment and Work Motivation." *Psychologica Belgica* 48:219-41.

Gagne, M., and E. L. Deci. 2005. "Self-determination Theory and Work Motivation." *journal of Organization Behavior* 26(4):331-62.

Gambardella, A., Paola Giuri, and Alessandra Luzzi. 2007. "The Market for Patents in Europe." *Research Policy* 36(8):1163-83.

Gambardella, Alfonso, Dietmar Harhoff, and Bart Verspagen. 2008. "The Value of European Patents." *European Management Review* 5.

Gardner, H. 1993. "Seven Creators of Modern Era." Pp. 28-47 in *Creativity*, edited by J. Brockman. New York: Simon and Schuster.

General Social Survey. 2001. "General Social Survey."

Gibbons, Michael, Camille Limoges, Helga Novotny, Simon Swhwartzman, Peter Scott, and Martin Trow. 1994. *The New Production of Knowledge: The Dynamics of Science and REsearch in Contemporary Societies*. London: Sage.

Giuri, P, M Mariani, and et al. 2007. "Inventors and invention processes in Europe: Results from the PatVal-EU survey." *Research Policy* 36:1107–27.

Glaser, B. G. 1963. "The Local-Cosmopolitan Scientists." *American Journal of Sociology* 69(3):249-59.

Gouldner, A. W. 1957a. "Cosmopolitans and Locals: Toward an Analysis of Latent Social Roles." *Administrative Science Quarterly* 2(3):281-306.

—. 1957b. "Cosmopolitans and Locals: Toward an Analysis of Latent Social Roles-I." *Administrative Science Quarterly* 2(2):281-306.

—. 1958. "Cosmopolitans and Locals: Toward an Analysis of Latent Social Roles-II." *Administrative Science Quarterly* 2(4):444-80.

Grant, A. M., and J. W. Berry. 2011. "The Necessity of Others is the Mother of Invention: Intrinsic and Prosocial Motivations, Perspective Taking, and Creativity." *Academy of Management Journal* 54(1):73-96.

Grant, Adam M. 2008. "Does intrinsic motivation fuel the prosocial fire? Motivational synergy in predicting persistence, performance, and productivity." *Journal of Applied Psychology* 93(1):48-58.

Griliches, Z. 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica* 25(4):501-22.

Gruber, M., D. Harhoff, and K. Hoisl. 2012. "Knowledge Recombination Across Technological Boundaries: Scientists vs. Engineers." *Management Science*.

Gupta, A. K., K. G. Smith, and C. E. Shalley. 2006. "The Interplay Between Exploration and Exploitation." *Academy of Management Journal* 49(4):693-706.

Haeussler, C., L. Jiang, J. Thursby, and M. Thursby. 2009. "Specific and General Information Sharing Among Academic Scientists." *NBER Working Paper #15315*.

Hagedoorn, J. 2003. "Sharing intellectual property rights—an exploratory study of jointpatenting amongst companies." *Industrial Corporate Change* 12:1035-50.

Hagstrom, W. D. 1964. "Traditional and Modern Forms of Teamwork." *Administrative Science Quarterly* (9):241-63.

—. 1967. "Competition and Teamwork in Science." Madison, Wis: University of Wisconsin.

Haigh, W. T., and D. E. Gladkowski. 1992. "Reward Strategy for Motivating R&D Organization Performance." *Perspectives in Total Compensation* 2(4):1-8.

Hall, B. H., and R. H. Ziedonis. 2001. "The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995." *RAND Journal of Economics* 32(1):101-28.

Hargadon, A. 2003. *How Breakthroughs Happen: The Surprising Truth about How Companies Innovate*. Cambridge, MA: Harvard Business School Press.

—. 2006. "Bridging and Building: Toward a Microsociology of Creativity." in *Creativity and Innovation in Groups and Teams*, edited by L. Thompson. Mahwah, NJ: Lawrence Erlbaum.

—. 2008. "Creativitiy that Works." in *Handbook of Organizational Creativity*, edited by Jing Zhou and Christina E. Shalley: Psychology Press.

Hargadon, A., and R. Sutton. 1997. "Technology Brokering and Innovation in a Product Development Firm." *Administrative Science Quarterly* 42(4):716-49.

Harhoff, Dietmar, Francis Narin, F. M. Scherer, and Katrin Vopel. 1999. "Citation Frequency and the Value of Patented Inventions." *Review of Economics and Statistics* 81(3):511-15.

Harris, Christopher G., Robert Arens, and Padmini Srinivasan. 2010. "Comparison of IPC and USPC classification systems in patent prior art searches." Pp. 27-32 in *Proceedings of the 3rd international workshop on Patent information retrieval*. Toronto, ON, Canada: ACM.

Heffner, A. G. 1979. "Authorship Recognition of Suborinates in Collaborative Research." *Social Studies of Science* (9):377-84.

Henderson, R., and K Clark. 1990. "Architectural Innovation: The Reconfiguration of Existing PRoduct Technologies and Failure of Established Firms." *Administrative Science Quarterly* 35:9-30.

Hennessey, B. A., and T. M. Amabile. 1998. "Reward, Intrinsic Motivation, And Creativity." *American Psychologist* 53(6):674-75.

Herrbach, O. 2006. "A Matter of Feeleing? The Affective Tone of Oranizational Commitment and Identification." *journal of Organization Behavior* 27:629-43.

Hesse, Bradford W., Lee S. Sproull, Sara B. Kiesler, and John P. Walsh. 1993. "Returns to Science: Computer Networks and Scientific Research in Oceanography." *Communications of the ACM* 36(8):90-101.

Hessels, Laurens K., and Harro van Lente. 2008. "Re-thinking New Knowledge Production: A Literature Review and a Research Agenda." *Research Policy* 37:740-60.

Hicks, D. 1993. "University-Industry Research Links in Japan." *Policy Science* 26(4):361-95.

Hicks, D., and K. Katz. 1996. "Where is Science Going?" *Science, Technology, and Human Values* 21(4):379-406.

Hicks, D., and F. Narin. 2001. "Strategic Research Alliance and 360 Degree Bibliometric Indicators." in *NSF Workshop on Strategic Research Partnership*: NSF.

Hong, Lu, and Scott E. Page. 2004. "Groups of diverse problem solvers can outperform groups of high-ability problem solvers." *PNAS* 101(46):16385-89.

Huang, Hsini. 2012. "One Size Does not Fit All: Regional Ecology, Firm Size, and Innovation Performance." in *School of Public Policy*. Atlanta, GA: Georgia Institute of Technolgoy.

Hull, C. L. 1943. *Principles of behavior*. New York: Appleton-Century-Crofts.

Hunter, Larry W., and Sherry M. B. Thatcher. 2007. "Feeling the heat: Effects of stress, commitment, and job experience on job performance." *Academy of Management Journal* 50(4):953-68.

Israel, P. B. 1998. *Edison: A Life of Invention*. New Yrok: John Wiley.

Jaffe, A. B., M. Trajtenberg, and R. Henderson. 1993. "Geographic Localization of Knolwedge Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics* 108(3):577-98.

Janis, I. L. 1971. "Groupthink." *Psychology Today* 5(6):43-46, 74-76.

—. 1972. *Victims of Groupthink: a Psychological Study of Foreign-Policy Decisions and Fiascoes*. Boston: Houghton Mifflin.

Jehn, K. A., G. B. Northcraft, and M. A. Neale. 1999. "Why Differences Make a Difference: A Field Study of Diversity, Conflict, and Performance in Workgroups." *Administrative Science Quarterly* 44(4):741-63.

Jenkins, G. D., N. Gupta, A. Mitra, and J. D. Shaw. 1998. "Are financial incentives related to performance? A meta-analytic review of empirical research." *Journal of Applied Psychology* 83:777-87.

Jones, B. F. 2009. "The Burden of Knowledge and the "Death of the Renaissance Man": Is Innovation Getting Harder?" *Review of Economic Studies* 76(1):283-317.

Judge, W. Q., G. E. Fryxell, and R. S Dooley. 1997. "The New Task of R&D Management: Creating Goal-Directed Communities for Innovation." *California Management Review* 39(3):72-85.

Jung, Hyun Ju, and Jeongsik "Jay" Lee. 2012. "The Impacts of Commercialization-Oriented Science and Technology Programs on University Research: The Case of the U.S. National Nanotechnology Initiative." Georgia Institute of Technology.

Jung, T. 2009. "Uses and Nonuses of Patented Invention." Atlanta, GA: Georgia Institute of Technology.

Kanfer, R., and P. L. Ackerman. 2000. "Individual Differences in Work Motivation: Further Exploration of a Trait Framework." *Applied Psychology: An International Review* 49:470-82.

Kanfer, R., and E. D. Heggestad. 1997. "Motivational Traits and Skills: A Person-Centered Approach to Work Motivation." Pp. 1-56 in *Research in Organizational Behavior*, edited by L. L. Cummings and B. M. Staw. Greenwich, CT: JAI Press, Inc.

—. 1999. "Individual Differences in Motivation." Pp. 293-313 in *Learning and Individual Differences: Process, Trait, and Content Determinants*, edited by P. L. Ackerman, P. C. Kyllonen, and R. D. Roberts. Washington D. C.: American Psychological Association.

Kankanhalli, A., B. C. Y. Tan, and K. K. Wei. 2005. "Contributing Knowledge to Electronic Repositories: An Empirical Investigation." *MIS Quarterly* 29(1):113-43.

Katila, R., and G. Ahuja. 2002. "Something Old, Something New: A Longitudinal Study of Search Behavior and NEw Product Development " *Academy of Management Journal* 45(6):1183-94.

Katz, J. R., and B. R. Martin. 1997. "What is Research Collaboration?" *Research Policy* 26(1):1-18.

Kerr, S., and M. A. Von Glinow. 1977. "Issues in the Study of "Professionals" in Organizations: The Case of Scientists and Engineers." *Organizational Behavior and Human Performance* 18(329-345).

Kogut, B., and U. Zander. 1992. "Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology." *Organization Science* 3(3):383-97.

—. 1996. "What Firms Do? Coordination, Identity, and Learning." *Organization Science* 7(5):502-18.

Konovsky, M. A. 2000. "Understanding procedural justice and its impact on business organizations." *Journal of Management* 26(3):489-511.

Kornhauser, W. 1962. *Scientists in Industry: Conflict and Accomodation*. Berkeley, CA: University of California Press.

Kouzes, Richard T., James D. Myers, and William A. Wulf. 1996. "Collaboratories: Doing Science on the Internet." *IEEE Computer* 29(8):40-46.

Kuvaas, Bard. 2006. "Work Performance, Affective Commitment, and Work Motivation: The Roles of Pay Administration and Pay Level." *journal of Organization Behavior* 27:365-85.

Lai, Ronald, Alexander D'Amour, Amy Yu, Ye Sun, and Lee Fleming. 2011. "Disambiguation and Co-authorship Networks of the U.S. Patent Inventor Database (1975 - 2010)." http://hdl.handle.net/1902.1/15705 UNF:5:RqsI3LsQEYLHkkg5jG/jRg== V4 [Version].

Landry, Rejean, and Nabil Amara. 1998. "The Impact of Transaction Costs on the Institutional Structuration of Collaborative Academic Research." *Research Policy* 27(9):901-13.

Lanjouw, Jean O., and Mark Schankerman. 2004. "Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators." *The Economic Journal* 114(495):441-65.

Laursen, Keld, and Ammon J. Salter. 2006. "Open for Innovation: The Role of Openness in Explaining Innovation Performance among UK Manufacturing Firms." *Strategic Management Journal* 27(2):131-50.

Lawler, E. E. III. 1981. *Pay and Organizational Development*. Reading, MA: Addison-Wesley.

Lee, S., and B. Bozeman. 2005. "The Impact of Research Collaboration on Scientific Productivity." *Social Studies of Science* 35(5):673-702.

Leonard-Barton, D., and W. Swap. 1999. *When Sparks Fly: Igniting Creativity in Groups*. Boston: Harvard Business Press.

Lerner, Joshua. 1994. "The Importance of Patent Scope: An Empirical Analysis." *RAND Journal of Economics* 25(2):319-33.

Levin, S. G., and P. E. Stephan. 1991. "Research Productivity over the Life Cycle: Evidence for Academic Scientists." *American Economics Review* 81:114-32.

Levinthal, D. A. 1998. "The Slow Pace of Rapid Technological Change: Gradualism and Punctuation in Technological Change." *Industrial Corporate Change* 7:217-47.

Lin, H. F. 2007. "Effects of Extrinsic and Intrinsic Motivation on Employee Knowledge Sharing Inentions." *Journal of Information Science* 33(2):135-49.

Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage Publications.

Maanten, A. A. 1970. "Statistical Analysis of a Scientific Discipline: Psychology." *Earth Science Review* (6):181-218.

Mael, F. A., and B. E. Ashforth. 1995. "Loyal from Day One: Biodata, Organizational Identification, and Turnover among Newcomers." *Personnel Psychology* 48:309-33.

March, James G. 1991. "Exploration and Exploitation in Organizational Learning." *Organization Science* 2(1):71-87.

March, James G., and Herbert A. Simon. 1958. *Organizations*. New York: Wiley.

Marx, Karl. 1932. *Economics and Philosophical Manuscripts of 1844*. Moscow: Progress Publisher.

Mathieu, J. E., and D. M. Zajac. 1990. "A Review and Metaanalysis of the Antecedents, Correlates, and Consequences of Organizational Commitment." *Psychological Bulletin* 108(2):171-94.

Mayo, E. 1945. *The Social Problems of an Industrial Civilization*. Cambridge, MA: Harvard University Press.

Melin, Goran. 2000. "Pragmatism and Self-organization: Research Collaboration on the Individual Level." *Research Policy* 29(1):31-40.

Merton, R. 1957. *Social Theory and Social Structure*. Glencoe, IL: Free Press.

—. 1968. "The Mathew Effect in Science: The Reward and Communication Systems of Science are Considered." *Science* 159(3810):56.

—. 1973a. "Priorities in Scientific Discovery." Pp. 286-324 in *The Sociology of Science*, edited by N. Storer. Chicago: University of Chicgo Press.

—. 1973b. *The Sociology of Science: Theoretical and Empirical Investigation*. Chicago, IL.: University of Chicago Press.

Meyer, J. P., and N. J. Allen. 1991. "A Three-Component Conceptualization of Organizational Commitment." *Human Resource Management Review* 1(1):61-89.

Meyer, J. P., T. E. Becker, and C. Vandenberghe. 2004. "Employee commitment and motivation: a conceptual analysis and integrative model." *Journal of Applied Psychology* 89(6):991-1007.

Meyer, J. P., and E. R. Maltin. 2010. "Employee commitment and well-being: A critical review, theoretical framework and research agenda." *Journal of Vocational Behavior* 77(2):323-37.

Meyer, J. P., D. J. Stanley, L. Herscovitch, and L. Topolnytsky. 2002. "Affective, continuance, and normative commitment to the organization: A meta-analysis of antecedents, correlates, and consequences." *Journal of Vocational Behavior* 61(1):20-52.

Miliken, F. J., C. A. Bartel, and T. R. Kurtzberg. 2003. "Diversity and Creativity in Work Groups." in *Group Diversity: Innovation through Collaboration*, edited by P. B. Paulus and B. Nijstads. London: Oxford University Press.

Miller, G. A. 1967. "Professionals In Bureaucracy- Alienation Among Industrial Scientists And Engineers." *American Sociological Review* 32(5):755-68.

Mohrman, S. A., C. B. Gibson, and A. M. Mohrman. 2001. "Doing research that is useful to practice: A model and empirical exploration." *Academy of Management Journal* 44(2):357-75.

Morin, Alexandre J. S., Christian Vandenberghe, Jean-Sebastien Boudrias, Isabelle Madore, Julien Morizot, and Michel Tremblay. 2011. "Affective commitment and citizenship behaviors across multiple foci." *Journal of Managerial Psychology* 26(7-8):716-38.

Mottaz, C. J. 1988. "Detreminants of Organizational Commitment." *Human Relations* 41:467-82.

Mowday, R. T., L. W. Porter, and R. Dublin. 1974. "Unit Performance, Situational Factors, and Employee Attitudes in Spatially Separated Work Units." *Organizational Behavior and Human Performance* 12:231-48.

Mowday, R. T., R. M. Steers, and L. W. Porter. 1979. "The Measurement of Organizational Commitment." *Journal of Vocational Behavior* 14:224-47.

Mukhergee, A., and Scott Stern. 2009. "Disclosure or Secrecy? The Dynamics of Open Science." *International Journal of Industrial Organization* 27(3):449-62.

Mumford, M. D., and S. B. Gustafson. 1988. "Creativity Syndrome: Integration, Application, and Innovation." *Psychological Bulletin* 103:27-43.

Nagaoka, Sadao, and John P. Walsh. 2009. "Commercialization and other uses of patents in Japan and the US: Major findings from the RIETI-Georgia Tech inventor survey." RIETI Working Paper.

Nahapiet, J., and S. Ghoshal. 1998. "Social Capital, Intellectual Capital, and the Organizational Advantage." *Academy of Management Review* 23:242-66.

National Science Foundation. 2012. "Science and Engineering Indicators." edited by National Science Foundation.

Nelson, R. R. 1959. "The Simple Economics of Basic Scientific Research." *Journal of Political Economy* 67(3):297-306.

Nelson, R. R., and S. Winter. 1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA: Belknap Press.

Nerkar, A., and Scott Shane. 2007. "Determinants of Invention Commercialization: An Empirical Examination of Academically Sourced Inventions." *Strategic Management Journal* 28(11):1155-66.

Nonaka, I. 1994. "A Dynamic Theory of Organizational Knowledge Creation." *Organization Science* 5:14-37.

Norton, E. C., Hua Wang, and C. Ai. 2004. "Computing Interaction Effects and Standard Errors in Logit and Probit Models." *The Stata Journal* 4(2):154-67.

Nunally, J.C. Jr. 1978. *Introduction to Psychological Measurement*. New York: McGraw-Hill.

Oldham, G. R., and A. Cummings. 1996. "Employee Creativity: Personal and Contextual Factors at Work." *The Academy of Management Journal* 39(3):607-34.

Osborn, A. 1957. *Applied Imangination*. New York: Scribner.

Osterloh, M., and B. Frey. 2000. "Motivation, Knowledge Transfer, and Organizational Forms." *Organization Science* 11(5):538-50.

Pelled, L. H. 1996. "Demographic Diversity, Conflict, and Work Group Outcome: An Intervening Process Theory." *Organization Science* 7(6):615-31.

Pelz, D. C. 1956. "Some Social Factors Related to Performance in a Research Organization." *Administrative Science Quarterly* 1:310-12.

—. 1976. "Problem Solvers vs. Decision Makers." in *Scientists in Organizations: Productive Climates for Research and Development*, edited by D. C. Pelz and F. M. Andrews. Ann Arbor, MI: Institute for Social Research, The University of Michigan.

Pelz, D. C., and F. M. Andrews. 1976. *Scientists in Organizations: Productive Climates for Research and Development*. Ann Arbor: Institute for Social Research, University of Michigan.

Perlow, L. S. 1997. *Finding Time: How Corporations, Individuals and Families Can Benefit from New Work Practices*. Ithaca, NY: Cornell University Press.

Perry-Smith, J. E. 2006. "Social Yet Creative: The Role of Social Relationship in Facilitating Individual Creativity." *Academy of Management Journal* 49(1):85-101.

Perry-Smith, J. E., and Christina E. Shalley. 2003. "The Social Side of Creativity: A Static and Dynamic Social Network Perspective." *Academy of Management Journal* 49:85-101.

Podolny, J. M. 2005. *Status Signals*. Princeton, NJ: Princeton University Press.

Podsakoff, P. M., S. B. MacKenzie, J. B. Paine, and D. G. Bachrach. 2000. "Organizational citizenship behaviors: A critical review of the theoretical and empirical literature and suggestions for future research." *Journal of Management* 26(3):513-63.

Porter, L. W., R. M. Steers, R. T. Mowday, and P. V. Bouilian. 1974. "Organizational Commitment, Job Satisfaction, and Turnover Among Psychiatric Technicians." *Journal of Applied Psychology* 59:603-09.

Powell, W. W., and E. Giannella. 2010. "Collective Invention and Inventor Networks." Pp. 575-605 in *Economics of Innovation, Volume 1*, edited by B. Hall and Nathan Rosenberg. Amsterdam, The Netherlands: Elsevier.

Powell, W. W., Kenneth W. Koput, and Laurel Smith-Doerr. 1996. "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology." *Administrative Science Quarterly* 41(1):116-45.

Pratt, M. G. 1998. "To Be or Not To Be? Central Questions in Organizational Identifications." Pp. 171-207 in *Identity in Organizations: Building Theory Through Conversations* edited by D. A. Whetten and P. C. Godfery. Thousand Oaks, CA: Sage.

Presser, S. 1980. "Collaboration and the Quality of Research." *Social Studies of Science* (10):95-101.

Quigley, N. R., P. E. Tesluk, E. A. Locke, and K. M. Bartol. 2007. "A Multilevel Investigation of the Motivational Mechanism Underlying Knowledge Sharing and Performance." *Organization Science* 18(1):71-88.

Randall, D. M., D. B. Fedor, and C. O. Longenecker. 1990. "The Behavioral Expression of Organizational Commitment." *Journal of Vocational Behavior* 36(2):210-24.

Reagans, R., and E. W. Zuckerman. 2001. "Networks, Diversity, and Productivity: The Social Capital of Corporate R&D Teams." *Organization Science* 12(4):502-17.

Riketta, M. 2002. "Attitudinal organizational commitment and job performance: a meta-analysis." *Journal of Organizational Behavior* 23(3):257-66.

—. 2005. "Organizational Identification: A Meta-Analysis." *Journal of Vocational Behavior* 66:358-84.

Ritti, R. . 1968. "Work Goals of Scientists and Engineers." *Industrial Relations* 10(2):296-310.

Roberts, Edward B. 1988. "Managing Invention and Innovation." *Research Technology Management* 31(1):11-27.

Rogers, E. 1995. *The Diffusion of Innovation*. New York: Free Press.

Rothaermel, F. T., and D. L. Deeds. 2004. "Exploration and Exploitation Alliances in Biotechnology: A System of New Product Development." *Strategic Management Journal* 25:201-21.

Rothaermel, F. T., and Andrew M. Hess. 2007. "Building Dynamic Capabilities: Innovation Driven by Individual-, Firm-, and Network-Level Effects." *Organization Science* 18:898-921.

Ryan, R. M., and E. L. Deci. 2000. "Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions." *Contemporary Educational Psychology* 25(1):54-67.

Sakakibara, M. 2002. "Formation of R&D consortia: Industry and company effects." *Strategic Management Journal* 23(11):1033-50.

Sauermann, H. 2005. "Vocational Choice: A Decision Making Perspective." *Journals of Vocational Behavior* 66:273-303.

Sauermann, Henry, and Wesley M. Cohen. 2010. "What Makes Them Tick? Employee Motives and Firm Innovation." *Management Science* 56(12):2134-53.

Sauermann, Henry, and Paula E. Stephan. 2010. "Twins or Strangers? Differences and Similarities between Industrial and Academic Science." *NBER Working Paper #16113*.

Schmookler, J. A. 1962. "Economic Sources of Inventive Activity." *Journal of Economic History* 22:1-20.

Schmookler, Jacob. 1954. "The Level of Inventive Activity." *Review of Economics & Statistics* 36(2):183.

Schumpeter, Joseph A. 1934. *The Theory of Economic Development; An Inquiry into Profits, Capital, Credit, Interest, and Business Cycle.* Cambridge, MA: Harvard University Press.

—. 1939. *Business Cycles*. New York: McGraw-HIll Book Company, Inc.

Schumpeter, Joseph A. . 1942. *Capitalism, Socialism and Democracy*: Harper Perennial.

Senge, P. 1990. *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Currency/Doubleday.

Shalley, C. E., J. Zhou, and G. R. Oldham. 2004. "The effects of personal and contextual characteristics on creativity: Where should we go from here?" *Journal of Management* 30(6):933-58.

Shalley, Christina E. 1995. "Effects of Coaction, Exepected Evaluation, and Goal Setting on Creativity and Productivity." *Academy of Management Journal* 38:483-503.

—. 2008. "Creating Roles: What Managers Can Do to Establish Expectations for Creative Performance." in *Handbook of Organizational Creativity*, edited by Jing Zhou and Christina E. Shalley. Mawah, NJ: Lawrence Erlbaum.

Shalley, Christina E., and G. R. Oldham. 1997. "Competition and Creative Performance: Effects of Competitor Presence and Visibility." *Creativity Research Journal* 10:337-45.

Shalley, Christina E., and J. E. Perry-Smith. 2001. "Effects of Social-Psychological Factors on Creative Performance: The Role of Informational and Controlling

Expected Evaluation and Modeling Experiences " *Organizational Behavior and Human Decision Processes* 84:1-22.

Shepard, H. A. 1956. "Nine Dilemmas in Industrial Research." *Administrative Science Quarterly* 1(3):295-309.

Shin, S. J., and J. Zhou. 2003. "Transformational leadership, conservation, and creativity: Evidence from Korea." *Academy of Management Journal* 46(6):703-14.

Simonton, D. K. 1999. *Origins of Genius: Darvinian Perspectives on Creativity*. New York: Oxford University Press.

Singh, Jasjit, and Lee Fleming. 2010. "Lone Inventors as Sources of Breakthroughs: Myth or Reality?" *Management Science* 56:41-56.

Skinner, B. F. 1953. *Science and Human Behavior*. New York: MacMillan.

Sobel, M. E. 1982. "Asymptotic Confidence Intervals for Indirect Effects in Structural Equation Models." *Sociological Methodology* 13:290-312.

Stein, Morris. 1953. "Creativity and Culture." *Journal of Psychology* 36(2):311-22.

—. 1963. "A Transactional Approach to Creativity." Pp. 217-27 in *Scientific Creativity: Its Recognition and Development*, edited by C. W. Taylor and F. Barron. New York: Wiley.

Stephan, P. E. 1996. "The Economics of Science." *Journal of Economic Literature* 34(3):1199-235.

—. 2010. "The Economics of Science." Pp. 218-66 in *Handbook of the Economics of Innovation*, edited by Bronwyn H. Hall and Nathan Rosenberg. Amsterdam, The Netherlands: North-Holland.

Stephan, P. E., and S. S. Everhart. 1998. "The Changing Rewards to Science: The Case of Biotechnology." *Small Business Economics* 10(2):141-51.

Stephan, P. E., and S. G. Levin. 1996. "Property Rights and Entrepreneurship in Science." *Small Business Economics* 8(3):177-88.

Stephan, P.E., and Sharon G. Levin. 1992. *Striking the Mother Lode in Science*: Oxford University Press.

Stern, Scott. 2004. "Do Scientists Pay To Be Scientists?" *Management Science* 50(6):835-53.

Storer, N. W. 1966. *The Social System of Science*. New York: Holt, Rinehart and Winston.

Stuart, T. E., H. Hoang, and R. C. Hybels. 1999. "Interorganizational Endorsements and the Performance of Entrepreneurial Ventures." *Administrative Science Quarterly* 44(2):315-18.

Szulanski, G. 1996. "Exploring Internal Stickiness: Impediments to the Transfer of Best Practice within the Firm." *Strategic Management Journal* 17:27-43.

Szulanski, G., R. Cappetta, and R. J. Jensen. 2004. "When and How Trust Worthiness Matters: Knowledge Transfer and Moderating Effect of Causal Ambiguity." *Organization Science* 15:600-13.

Thorsteindottir, O. H. 2000. "External Research Collaboration in Two Small Science Systems." *Scientometrics* 49(1):145-60.

Thursby, J. G., and M. C. Thursby. 2011. "Faculty participation in licensing: Implications for research." *Research Policy* 40(1):20-29.

Thursby, M., J. Thursby, and S. Gupta-Mukherjee. 2007. "Are there real effects of licensing on academic research? A life cycle view." *Journal of Economic Behavior & Organization* 63(4):577-98.

Tierney, P., S. M. Farmer, and G. B. Graen. 1999. "An examination of leadership and employee creativity: The relevance of traits and relationships." *Personnel Psychology* 52(3):591-620.

Tong, X. S. , and J. D. Frame. 1994. "Measuring National Technological Performance With Patent Claims Data." *Research Policy* 23(2):133-41.

van Knippenberg, D., and E. Sleebos. 2006. "Organizaional Identification versus Organizational Commitment: Self-Definition, Social-Exchange, and Job Attitude." *journal of Organization Behavior* 27:571-84.

Vandenberghe, C., K. Bentein, and F. Stinglhamber. 2004. "Affective commitment to the organization, supervisor, and work group: Antecedents and outcomes." *Journal of Vocational Behavior* 64(1):47-71.

von Hippel, E.A. 1988. *Sources of Innovation*. Oxford: Oxford University Press.

—. 2005. "Democratizing Innovation." in *SSRN eLibrary*.

Vroom, V. H. 1964. *Work and Motivation*. New York: Wiley.

Walsh, J. P., and T. Bayma. 1996. "The Virtual College." *The Information Society* 12(4):343-63.

Walsh, J. P., and Wesley M. Cohen. 2004. "Does the Golden Goose Travel?: A Comparative Analysis of the Influence of Public Research on Industrial R&D in the U.S. and Japan." in *American Sociological Association*. San Francisco.

Walsh, J. P., and Sadao Nagaoka. 2009. "How “Open” is Innovation in the US and Japan?: Evidence from the RIETI-Georgia Tech Inventor survey." in *RIETI Discussion Paper*: RIETI.

Walsh, J.P., and Shu-fen Tseng. 1998. "The Effects of Job Characteristics on Active Effort at Work." *Work and Occupations* 25:74-96.

Wasko, M. M., and S. Farag. 2005. "Why Should I Share? Examining Social Capital and Knowledge Contribution in Electronic Networks of Practice." *MIS Quarterly* 29(1):35-57.

Weick, K. E. 1995. *Sensemaking in Organizations*. Thousans Oaks, CA: Sage.

West, M. A. 1989. "Innovation among Health Care Professionals." *Social Behaviour* 4:173-84.

West, M. A., and J. L. Farr. 1989. "Innovation at Work: Psychological Perspectives." *Social Behaviour* 4:15-30.

Wiersma, U. J. 1992. "The Effects of Extrinsic Rewards in Intrinsic Motivation: A Metaanalysis." *Journal of Occupational and Organizational Psychology* 65(101-114).

Williamson, O. E. 1985. *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*. New York: Free Press.

Wood, D. J., and B. Gray. 1991. "Toward a Comprehensive Theory of Collaboration." *Journal of Applied Behavioral Science* 27(2):139-62.

Wooldridge, J. M. 2001. *Econometric Analysis of Cross Section and Panel Data*: MIT Press.

Wright, T. A., and D. G. Bonett. 2002. "The moderating effects of employee tenure on the relation between organizational commitment and job performance: A meta-analysis." *Journal of Applied Psychology* 87(6):1183-90.

Wuchty, S., B. F. Jones, and B. Uzzi. 2007. "The increasing dominance of teams in production of knowledge." *Science* 316(5827):1036-39.

Zucker, L. G., and M. R. Darby. 1996. "Star Scientists and Institutional Transformation: Patterns of Invention and Innovation in the Formation of the Biotechnology Industry." *Proceedings of the National Academy of Sciences* 93(23):12709-16.

Zucker, L. G., M. R. Darby, and J. S. Amstrong. 2002. "Commercializing Knowledge: Univeristy Science, Knowledge Capture, and Firm Performance in Biotechnology." *Management Science* 48(1):138-53.

Zucker, L. G., M. R. Darby, and M. B. Brewer. 1998. "Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises." *American Economics Review* 88(1):290-306.

Zuckerman, H. 1988. "The Sociology of Science." in *The Handbook of Sociology*, edited by N. J. Smelser: Sage.